California Regional Water Quality Control Board
Santa Ana Region

August 26, 2005

ITEM: 11

SUBJECT: **Public Workshop: Proposed Basin Plan Amendment – Incorporation of Total Maximum Daily Loads (TMDLs) for Nutrients for Big Bear Lake**

California Regional Water Quality Control Board
Santa Ana Region

Staff Report on the Nutrient Total Maximum Daily Loads for Big Bear Lake

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EXECUTIVE SUMMARY

This document describes the proposed Total Maximum Daily Loads (TMDLs) for nutrients for Big Bear Lake. Section 303(d) of the Clean Water Act (CWA) requires States to identify waters that do not or are not expected to meet water quality standards (beneficial uses, water quality objectives and the state's antidegradation policy) with technology-based controls. The States are then required to develop a TMDL for each of the constituents listed on the 303(d) list. The TMDL establishes the maximum load of a pollutant that can enter the listed water body without violating water quality standards. A TMDL is defined as the sum of the individual wasteload allocations for point sources, load allocations for nonpoint sources including natural background, and a margin of safety. Seasonal variations and critical conditions must also be addressed. The Regional Board placed Big Bear Lake on the 303(d) list in 1994 due to excessive nutrients and noxious aquatic plants. Rathbun (Rathbone) Creek, Summit Creek, and Grout Creek, tributaries to Big Bear Lake, were also included on the 1994 list due to excessive nutrients. The listings were based on the historic information summarized in Section 2.2 and Appendix A. Excessive nutrients and sediment deposition in Big Bear Lake have contributed to the eutrophic condition of the lake. The proliferation of two aquatic plants, primarily Eurasian watermilfoil (*Myriophyllum spicatum* L.) and Coontail (*Ceratophyllum demersum* L.), severely impact the beneficial uses of Big Bear Lake, including water contact recreation (REC1), non-contact water recreation (REC2), warm (WARM) and cold (COLD) freshwater habitat and wildlife habitat (WILD). The nutrients addressed by the TMDLs are nitrogen and phosphorus.

Rathbun Creek, Summit Creek, and Grout Creek contributed the highest nutrient loads to Big Bear Lake in 1992 and 1993, which led to their placement on the 303(d) list in 1994. Since that time, the creeks have been monitored periodically. Since the start of the watershed monitoring in 2001, high nutrient concentrations have been recorded at several locations on Rathbun Creek and Summit Creek , while there was not measurable flow in Grout Creek until late 2003. From 2001 to 2004, the Big Bear Lake watershed experienced extremely dry years and therefore, nutrient inputs to the lake from the watershed were very low. Algae mats have been observed in a few locations in both Rathbun Creek and Summit Creek during the summer. Data for the three creeks are located in Appendix A.

This document summarizes the information used by the California Regional Water Quality Control Board, Santa Ana Region (Regional Board) to develop proposed TMDLs for nitrogen and phosphorus for Big Bear Lake. No TMDLs are proposed at this time for the three creeks – Rathbun, Summit and Grout Creeks. Studies are necessary to assess beneficial use impairment in the creeks. After such studies are completed, data will be reviewed and a determination will be made to either develop TMDLs or remove the three creeks from the Section 303(d) list for nutrients.

TMDLs are recommended for nitrogen and phosphorus loading to Big Bear Lake under dry weather conditions only. Insufficient data for wet or average hydrologic conditions are available to allow calibration of the lake water quality model used to calculate the TMDLs. The proposed TMDL implementation plan addresses this deficiency. A phased TMDL approach is proposed to allow for requisite study and refinement of the TMDLs, including consideration of wet and average hydrological conditions. It is proposed that compliance with the final numeric targets identified in the recommended TMDLs be achieved as soon as possible but no later than 2015.

The components of the Big Bear Lake nutrient TMDLs include:

1. Problem Statement. This section reviews the historic information used to include Big Bear Lake on the 303(d) list, and summarizes existing conditions using historic data and data collected since the listing. Monitored nutrient concentrations have at times exceeded a regional numerical total phosphorus and total inorganic nitrogen standard for Big Bear Lake (150 μg/L). Nutrient enrichment has contributed to excessive plant and algae growth.

2. Numeric Targets. The proposed numeric targets for Big Bear Lake for causal indicators (i.e., total phosphorus and total nitrogen) were derived using two different methodologies (Table 3-1). The recommended interim numeric target for total phosphorus was identified using the 25^{th} percentile of recent monitoring data (2001-2002) from four main lake monitoring stations, while the final numeric targets for phosphorus and nitrogen were developed using an index system for lakes. The proposed numeric targets for response variables (i.e., macrophytes and chlorophyll *a*) were derived using three different methodologies (Table 3-1). The recommended interim numeric target for chlorophyll *a* was identified using the 25^{th} percentile of recent monitoring data (2001) from four main lake monitoring stations for the growing season (May 1-October 31), while the final numeric target for chlorophyll *a* was developed using an index system for lakes. The final numeric targets for macrophytes are recommended based on literature values.

3. Source Analysis. This section quantitatively evaluates all the sources of total phosphorus and total nitrogen to Big Bear Lake. The sources are subdivided into external and internal loads, as well as nonpoint and point sources. External nonpoint sources are from forest and resort land uses and atmospheric deposition; external point sources are from high density urban and residential runoff subject to an NPDES permit; internal nonpoint sources are from nutrient fluxes from the sediment and nutrient loads from macrophytes. External land use sources were simulated using the Hydrological Simulation Program Fortran (HSPF); atmospheric loads were based on literature values; nutrient fluxes from sediment and nutrient loads from macrophytes were derived empirically from experiments conducted in 2002 and 2003. Total nutrient loads to Big Bear Lake from all sources are summarized in Table 4-7. As shown, average loads for dry conditions (1999-2003), average conditions (1990-2003) and wet conditions (1993) are calculated. The intent is to examine variations in nutrient loading associated with different hydrologic conditions. However, for the purposes of the proposed TMDLs, only dry weather loads were used, given limitations in data available to calibrate the lake water quality model (WASP) (see #4).

4. Linkage Analyis and TMDL (Load Capacity). The linkage analysis for Big Bear Lake discusses the relationship between external and internal nutrient loads and their effects on lake water quality and beneficial uses. The Water Quality Analysis Simulation Program (WASP) was used to determine the loading capacity (TMDL) for nutrients in Big Bear Lake under dry weather conditions. The dry weather loading capacities for total phosphorus and total nitrogen for Big Bear Lake are shown in Tables 5-2 and 5-3.

5. TMDL Allocations. Proposed wasteload allocations for the Big Bear Lake TMDLs are shown in Tables 6-1 and 6-2. These apply to urban runoff (from residential and high density urban land uses), which is the sole point source in the watershed and is regulated under an NPDES permit. Load allocations for total nutrients in the lake are proposed for source categories (forest, resort, atmospheric deposition, nutrient fluxes from sediment, and nutrient loads from macrophytes) in proportion to expected reductions from specific sources after the implementation of lake restoration activities (Tables 6-1 and 6-2). The proposed WLA and LAs are expressed as annual averages for dry hydrological conditions only.

6. Seasonal Variation and Critical Conditions. There are inherent seasonal (and annual) variations in nutrient dynamics in lakes and creeks, including the rates of nutrient input and internal cycling. WASP was calibrated with data collected from 2001-2003, reflecting this variation. Likewise, simulations with WASP take this variation into account. In addition, with the exception of chlorophyll *a,* the recommended numeric targets are expressed as annual averages. (The chlorophyll *a* numeric target is proposed as a growing season (May 1-October 31) average, since algae are not a problem at other times of the year.) By setting the numeric targets as annual means, emphasis is not placed on day-to-day or month-to-month variations in water quality. Instead year-to-year variations and improving trends in water quality are the focus of the TMDLs. Consideration of critical conditions ensures that even under the worst water quality conditions, water quality standards will be met with the loads established in the TMDLs. The critical condition for attainment of aquatic life and recreational uses in Big Bear Lake occurs during the summer and during dry years. The nutrient TMDLs for Big Bear Lake address critical conditions by focusing on the control of the internal sediment loads that dominate during these periods.

7. Margin of Safety. The TMDLs contain an implicit margin of safety, based on conservative approaches (e.g., the derivation of numeric targets based on the 25^{th} percentile of data (2001-2002) for Big Bear Lake before the application of the aquatic herbicide Sonar; numeric targets are proposed as annual averages; and, the use of conservative assumptions in the WASP model setup, such as estimating a higher macrophyte density than what had been calculated previously).

8. Implementation Plan. This section describes the actions, regulatory tools and other measures necessary to achieve the TMDLs and wasteload and load allocations. Implementation of the proposed Big Bear Lake TMDLs is the responsibility of the United States Forest Service (USFS), Big Bear Mountain Resorts, the City of Big Bear Lake, the California Department of Transportation (Caltrans), the County of San Bernardino and the San Bernardino County Flood Control District (SBCFCD). Although not a responsible party, the Big Bear Municipal Water District has indicated its commitment to work as a cooperating entity to implement the nutrient TMDLs.

9. Monitoring Plan. In order to evaluate the effectiveness of actions and programs implemented pursuant to these TMDLs, the continuation of the existing watershed and lake water quality monitoring programs, with some minor modifications, as well as some additional monitoring elements, is recommended. Because the TMDLs are phased, follow-up monitoring and evaluation is essential to validate and revise the TMDLs as necessary.

1.0 INTRODUCTION

The proposed TMDLs for nutrients for Big Bear Lake are described in this document. Big Bear Lake was placed on the 303(d) list in 1994 for nutrients and noxious aquatic plants. Rathbun Creek, Summit Creek, and Grout Creek, which are tributary to the lake, were also placed on the 303(d) list in 1994 due to excessive levels of nutrients. However, at this time, TMDLs are not proposed for these creeks. Instead, because of uncertainties with respect to whether there is actual beneficial use impairment from nutrients in these creeks, staff recommends monitoring and a beneficial use assessment for these tributaries as identified in the implementation plan. The nutrients addressed in the TMDLs are nitrogen and phosphorus. The following paragraphs provide an introduction to the history of Big Bear Lake.

Big Bear Lake is a man-made reservoir created by the construction of Bear Valley Dam in 1883-84. The lake is located in the San Bernardino Mountains in San Bernardino County, approximately 100 miles northeast of Los Angeles and 40 miles northeast of the City of San Bernardino. It is the dominant feature of Big Bear Valley and its eastern area covers what was once a large flat meadow (Leidy 2003a, 6-11).

Frank E. Brown constructed the first dam in 1883-84 as a single arch dam across Bear Creek, a tributary of the Santa Ana River. During 1912, a 20-foot higher, multiple arch dam was completed downstream of the existing dam (Leidy 2003a, 12-16). These dams were constructed to store water for downstream irrigation uses in the Redlands/San Bernardino area.

In 1964, the Big Bear Municipal Water District (BBMWD) was created in an effort to develop programs and projects to stabilize the lake's water level. BBMWD is directed by a five-member elected Board of Directors. BBMWD's primary responsibility is the day-to-day management of Big Bear Lake, including the management of water releases, Bear Valley dam, recreation, and fisheries and wildlife. In January 1977, BBMWD acquired the title to the dam, the lake bottom, and the surface recreation rights of Big Bear Lake, for a purchase price of $4,700,000. Bear Valley Mutual Water Company (Mutual), which manages the distribution of lake water to downstream irrigation users, retained the water rights to Big Bear Lake (BBMWD 2002a). Mutual provides Big Bear Lake water as a source of domestic supply for users within its service area. BBMWD must provide Mutual with 65,000 acre-feet (af) of water in any rolling ten-year period. When Mutual needs water above this amount, BBMWD has several options. BBMWD can release water from the lake, or provide water from another source (i.e., groundwater or State Water Project)(BBMWD 2002a).

Big Bear Lake has a storage capacity of 73,320 acre-feet (af) and a water surface area of 2,971 acres at the elevation of the top of the dam (6743.2 feet). The lake is full at a gage height reading of 72.33 feet (Big Bear Watermaster 2001, 6). In order to maintain the recreational and wildlife uses of the lake, especially at the east end and other shallow areas, BBMWD implements a Lake Stabilization Program designed to stabilize Big Bear Lake within 15 feet of the dam elevation (i.e., in the range of 6728.2-6743.2 feet) over the long-term (BBMWD 2002a). Recreational uses of the lake are severely impacted if the lake level falls more than 15 feet (i.e., lake elevation of 6728.2 feet). Water levels have been measured continuously since July 1998 with the installation of a continuous lake level recorder by the BBMWD (Big Bear Watermaster 2001, 5). During most years, the lake level fluctuates no more than 3-5 feet, but during drought conditions, when no surface runoff from the surrounding watershed enters Big Bear Lake, the lake levels can fluctuate up to 15 feet. High evaporation levels, due to high wind and low humidity conditions, can remove up to 48 inches per year from the lake surface. This number varies seasonally, depending on temperature, lake level (and thus surface area), and other factors. Evaporation is calculated monthly, using precipitation, temperature and other data and is reported in BBMWD's annual Watermaster reports. Lake inflow is calculated monthly by the following formula: Inflow = Evaporation + Releases + Spills + Leakage + Net Withdrawals - Change in Storage. Inflow is calculated rather than measured (BBMWD, 2002a). Average annual inflow to Big Bear Lake approximates 17,300 af and adjusted evaporation approximates 11,300 af based on Watermaster data from 1977-2001 (Table 1-1).

The State Water Resources Control Board adopted Order WR No. 95-4 to assure adequate flows downstream of the dam to protect fisheries in Bear Creek. Order WR No. 95-4 requires minimum outflows of 0.3 cfs at Station B (300 feet below Bear Valley Dam) and 1.2 cfs at Station A (West Cub Creek confluence with Bear Creek) (BBMWD 2002a). Big Bear Lake is also utilized as a source of water for snow making operations. Snow Summit and Bear Mountain ski resorts can acquire a total of 1000 af of lake water per year (BBMWD 2002a).

Table 1-1. Big Bear Lake statistics

Lake Elevation	6743.2 feet
Lake length	7 miles
Average lake width	½ mile
Shoreline	22 miles
Max depth at dam	72.33 feet
Max lake capacity	73,320 acre-feet
Big Bear Valley Length	12.5 miles
Average inflow	17,300 af/year
Average outflow at dam[1]	5,510 af/year
Average evaporation rate[2]	11,300 af/year
Average lake capacity	58,500 af/year
Average detention time of water (avg lake capacity/avg outflow at dam)	11 years

Source: BBMWD 2002a; BBMWD 2002b
[1]Outflow includes dam releases, spills, leakage and withdrawals
[2]Evaporation is calculated with the Blaney Criddle formula using the estimated evaporation rate and the average surface area of the lake during the month (Big Bear Watermaster 2001, 6).

1.1 Big Bear Lake Watershed

The Big Bear Lake watershed is approximately 37 square miles and is drained by more than 10 streams (Figure 1-1). Local stream runoff and precipitation on the lake are the water supply inputs to Big Bear Lake. Big Bear Lake drains to Bear Creek, which is tributary to the Santa Ana River. Twelve percent of Big Bear Lake's drainage basin consists of the lake itself.

The mountain peaks surrounding the Big Bear Basin rise to approximately 7,800-8,600 feet along the southern rim of the lake. Some prominent peaks include Butler Peak (8,537 feet) to the west, Bertha Peak (8,198 feet) to the north, and Snow Summit (8,470 feet) to the south. The watershed is dominated by yellow pine and white fir; junipers and pinyon pine are found on the drier slopes. The lower reaches of most of the Big Bear Lake tributaries, particularly those in the eastern area, are underlain with older and younger alluvium. The western portion and the upper eastern portions of the lake are dominated by undifferentiated basement complex rocks, which are mostly impervious.

The underlying groundwater basin is used for domestic water supply of the Big Bear Valley and is mined in three ways: wells drilled into alluvial deposits, bedrock slant wells, and springs. During the 1970s, the Big Bear Lake watershed was divided into seven hydrographic subareas which were "based essentially on drainage boundaries, to facilitate the description of the region and for the tabulation of pertinent data according to a geographic locale"(Neste, Brudin, and Stone, Inc. 1973, 3-12). These hydrographic subareas are termed Village, Rathbone, Division, North Shore, Grout Creek, Mill Creek, and Gray's Landing (Neste, Brudin, and Stone, Inc. 1973, 3-14) (Figure 1-2). The City of Big Bear Lake Department of Water and Power (DWP), established in 1989, obtains its water from local groundwater and provides domestic water service to the city and areas outside the city limits. The Division, Village and Rathbone (Rathbun) subareas provide the groundwater used by the city (City of Big Bear Lake 1999, ER-31).

(A) Rathbun (Rathbone) Creek Subwatershed. The Rathbun Creek subwatershed is located in the Moonridge area south of Big Bear Lake. The subwatershed drains approximately 4090 acres of land (6.4 square miles), 30% within the City of Big Bear Lake and the remainder within the San Bernardino National Forest (Figure 1-3). There are four major drainages included in the Rathbun Creek subwatershed: Rathbun Creek, Deer Canyon, Sand Canyon, and Bow Canyon. Rathbun Creek is 3.5 miles long. The Rathbun Creek subwatershed is characterized by steep fluvial/V-shaped erosional and mildly sloping alluvial valley bottom types with elevations from 6700 to 8900 feet above sea level (USDA 1995, 1). Bear Mountain ski area is located in the upper reaches of Rathbun Creek, Deer Canyon and several unnamed drainages, while Snow Summit ski area is located within the headwaters of Summit Creek, which drains into the Rathbun Creek watershed. Most of the drainage area has been substantially altered by human activities. The paragraphs below describe the condition of Rathbun Creek from the confluence of Sand Canyon Channel to the mouth.

<u>*Sand Canyon Channel*</u>
Sand Canyon Channel merges with Rathbun Creek at Moonridge Road. This channel is an ephemeral stream dominated by snowmelt runoff. Soils in the area are coarse textured. The channel gradient is approximately 6 percent and is devoid of riparian vegetation. The channel is partially maintained by the San Bernardino County Flood Control District (SBCFCD) (USDA 1995, 3).

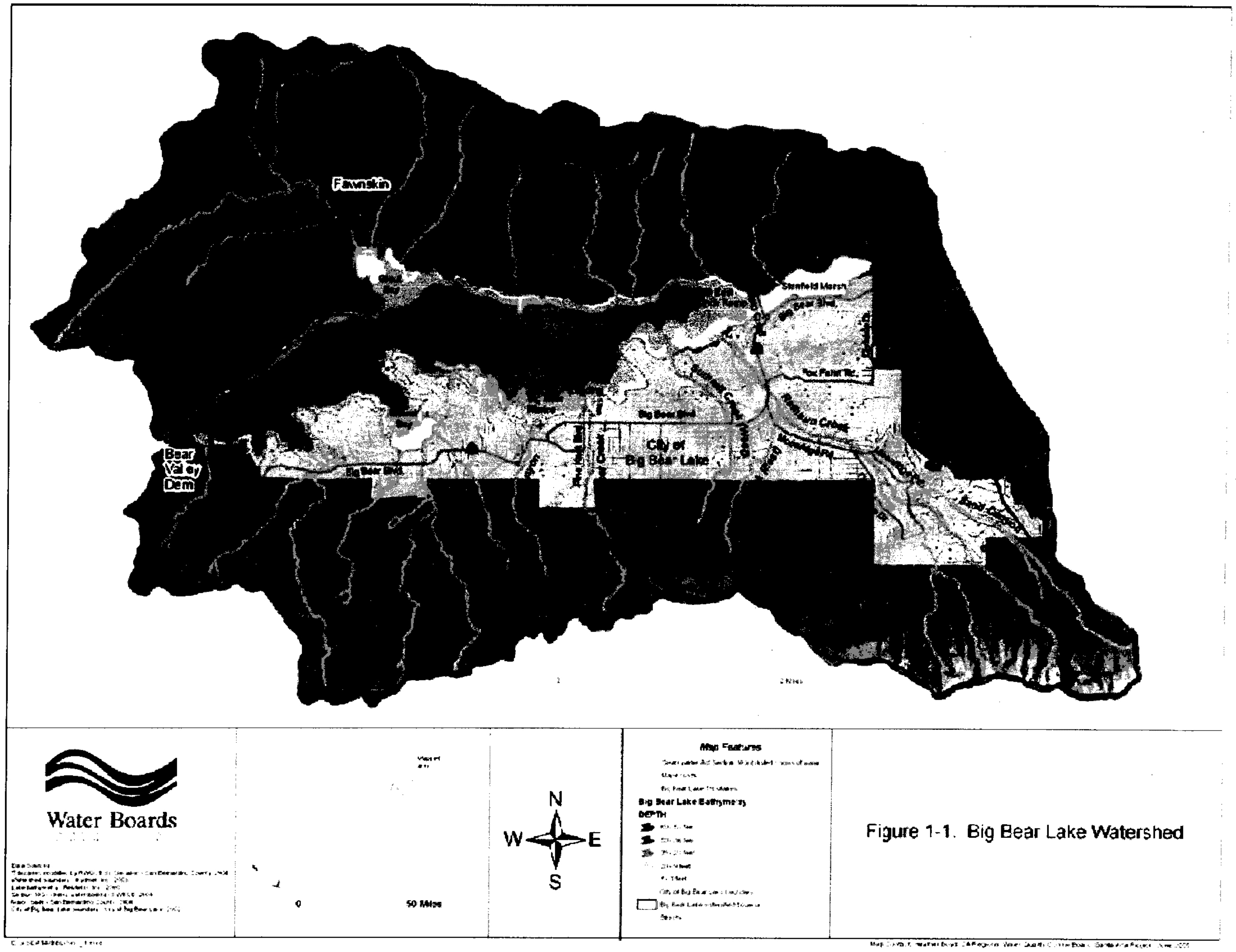


Figure 1-1. Big Bear Lake Watershed

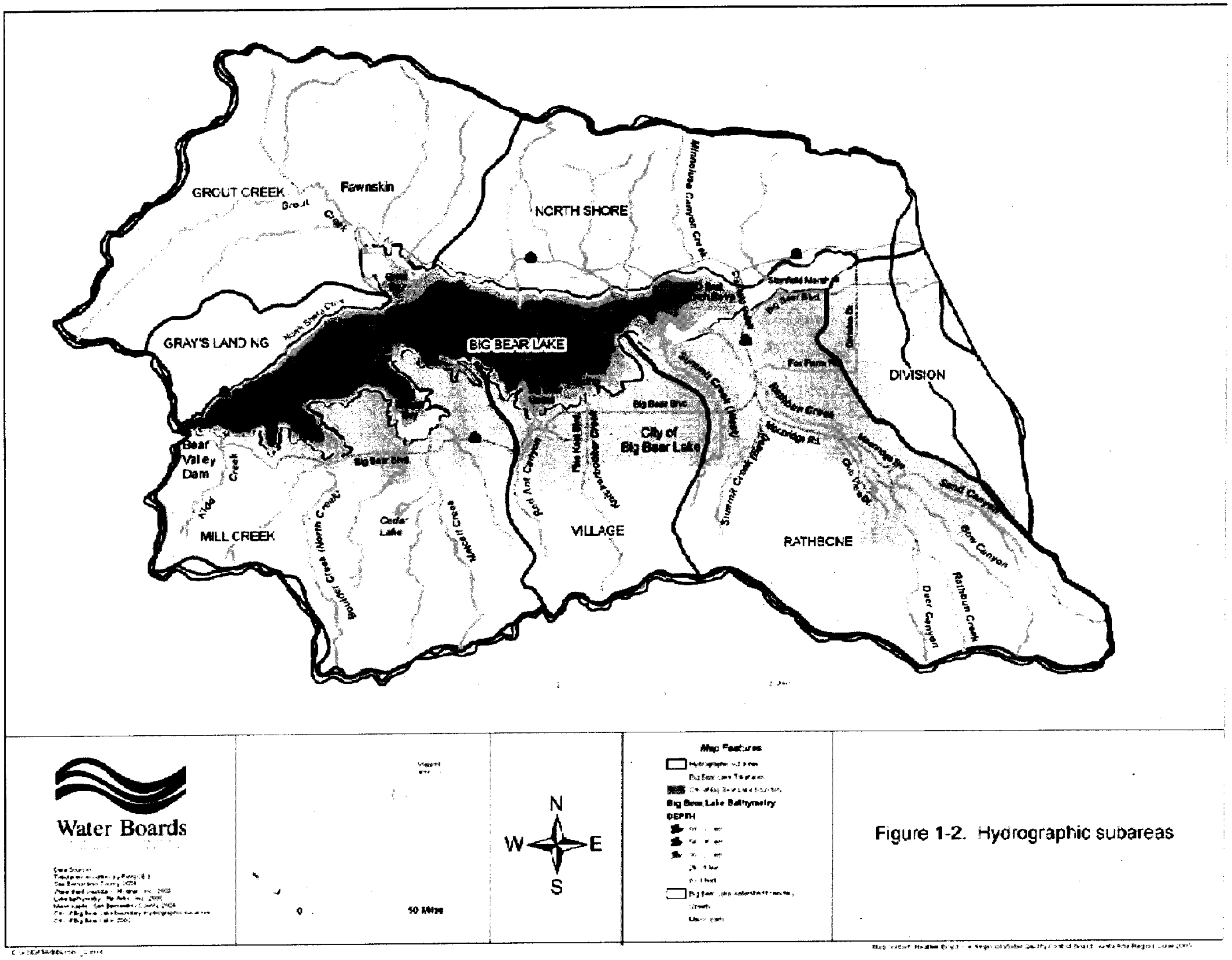


Figure 1-2. Hydrographic subareas

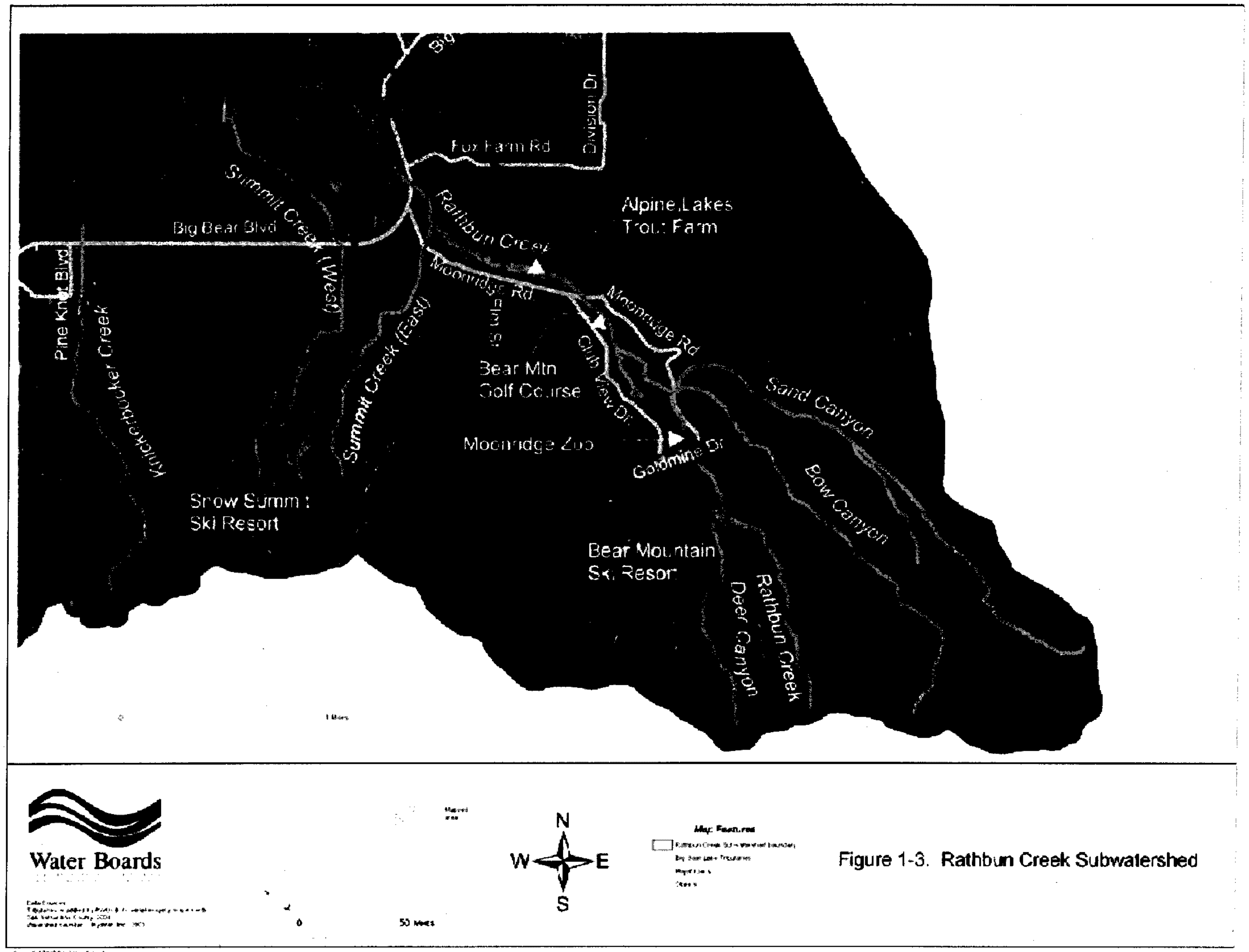


Figure 1-3. Rathbun Creek Subwatershed

Sand Canyon Channel has been widened to 40 feet, with 2:1 side slopes for flood protection for the nearby homes. The channel is unlined alluvial sediment consisting of fine to coarse-grained sands and gravels with interbedded silt (Black and Veatch 1990, 7). This channel is experiencing streambed erosion and bank sloughing (USDA 1995, 3). Modifications to Sand Canyon Channel, consisting of armoring the banks about 600 feet upstream of Moonridge Road, were completed in 1997 with funds from a Clean Water Act Section 319 (h) grant. In addition, supported by a Clean Water Act Section 319(h) grant awarded in 1999, the culvert at Teton Drive was replaced and the banks along the north and south sides of Teton Drive were armored. This project, located upstream of the first 319(h) project, was completed in 2002.

Rathbun Creek: Goldmine Road to Moonridge Road (Golf Course)

Historically, Rathbun Creek meandered, with flows from Sand and Bow Canyons joining the creek near the center of the valley. The upper portion of the creek was rerouted along the east side of the valley to allow for the golf course. This adjustment straightened the creek and in the process caused the creek to become entrenched (USDA 1995, 5). The 43-acre golf course was formerly a meadow (City of Big Bear Lake 1999, OPR-3). The Moonridge Zoo (2.7 acres) is located at the intersection of Moonridge and Goldmine Roads (City of Big Bear Lake 1999, OPR-3). Flow from the watershed area above Lassen Drive is directed into a culvert that outlets immediately below and to the west of the zoo. The lower portion of the creek, below the golf course to Moonridge Road, is a naturally meandering channel with a floodplain width between 30-50 feet. Horse grazing occurs below the golf course. Grazing has impaired the growth of riparian vegetation and contributes animal waste, high in nitrogen, which is discharged into the creek through surface runoff and leaching (USDA 1995, 5).

Rathbun Creek – Moonridge Road to the Trout Pond

A commercial trout pond (1 acre in size) is located within Rathbun Creek (City of Big Bear Lake 1999, OPR-3). Concrete check dams between Moonridge Road and Elm Road that serve as sediment traps are also effective as grade control structures. Below Elm Road there is a diversion that serves to divert moderate flows around the trout pond, while allowing low and high flows to continue flowing in the natural channel. Between Moonridge Road and the diversion downstream of Elm Road, the creek is straightened and channelized and consists of coarse loamy soils with an average channel slope of 2 percent (USDA 1995, 6-7).

Rathbun Creek – Trout Pond to State Highway 18

From the trout pond to Big Bear Boulevard (State Highway 18), the entire reach of Rathbun Creek is vegetated with tall shrub willows. After the installation of a 9x12 foot double box culvert under State Highway 18, a headcut developed in the upper section of this reach. Summit Creek drains the eastern edge of the Snow Summit Ski area. Runoff enters a trapezoidal concrete channel and flows through the residential area between the ski area and Moonridge Road. The creek (shown in Figure 1-3 as Summit Creek East) joins Rathbun Creek behind the Big Bear Inn through a 5x8 foot box culvert (USDA 1995, 8). A bank stabilization project was completed below the box culvert near the confluence of Summit and Rathbun Creeks in 1999. The banks were stabilized with rock and filter fabric (BBMWD 2002a).

Rathbun Creek – State Highway 18 to Big Bear Lake

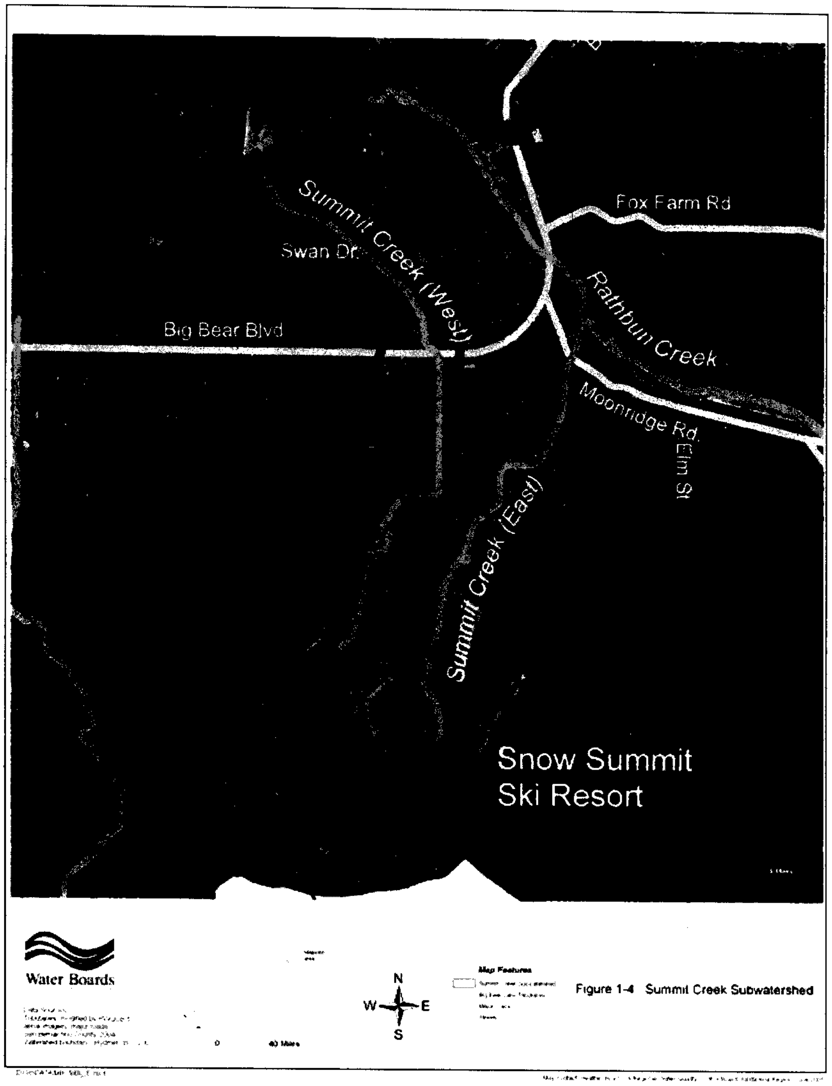
From State Highway 18 to Big Bear Lake, Rathbun Creek was historically a natural, meandering stream channel. The SBCFCD straightened and channelized the creek into an earth graded channel. Because of this channelization, sediment is not deposited throughout the floodplain but remains in creek flow and is deposited into the lake (USDA 1995, 9).

Bear Mountain Parking Areas
Two gravel overflow parking lots operated by Bear Mountain ski resort border Rathbun Creek. One parking lot covers approximately 20 acres and is bordered by Moonridge Road, Elm Road, and Rathbun Creek. The second parking lot is located upstream of the Trout Pond between Rathbun Creek and the diversion channel. This parking lot is approximately 5 acres in size. Plowed snow enters the creek. In addition, rain, ice melt, and snowmelt transport untreated sediment and pollutants into Rathbun Creek (USDA 1995, 16).

(B) Summit Creek Subwatershed. Summit Creek has a drainage area of approximately 0.55 square miles (Figure 1-4). All of the creeks that drain from Snow Summit are referred to as Summit Creek. The upper portion of the Snow Summit ski resort drains into the Rathbun Creek subwatershed. Summit Creek (also referred to as West Summit Creek) travels under Summit Boulevard until it reaches Park Avenue. Bear Valley Paving is located right below Park Avenue at Garstin Drive. The creek flows to the west of Bear Valley Paving and has been riprapped in places along both banks and realigned approximately 40-80 feet to the south of its previous location. At the junction of Swan Drive and Marina Point, a box culvert exists. The creek runs through the industrial section of the City of Big Bear Lake below State Highway 18.

(C) Grout Creek Subwatershed. The major town within the Grout Creek drainage basin (Figure 1-5) is Fawnskin, which is within the County's unincorporated areas. Other areas within this drainage basin are in the U.S. Forest Service (USFS) area. Grout Creek has a drainage area of approximately 4.5 square miles. Grout Creek is the longest tributary within the Big Bear Lake drainage basin at 3.8 miles long (Siegfried, Herrgesell, and Loudermilk 1979, 2), with a gradient of approximately 400 feet per mile (Neste, Brudin, and Stone, Inc. 1973, 2-3).

Climate. Precipitation varies greatly in the Big Bear area due to a rainshadow effect. The west end of the lake, near the dam, typically receives an average of 30-35 inches per year while at the east end of the lake, the average is less than 20 inches (Figure 1-6). The Big Bear Lake Dam weather station, established in 1883, has been monitoring precipitation continuously starting with the first precipitation records from the 1883-84 season. Information on other daily and hourly precipitation records in the San Bernardino Mountains is found in the modeling report (BBMWD, Hydmet, Inc. and AquAeTer, Inc. 2003).


Summit Creek (West)
Swan Dr
Fox Farm Rd
Big Bear Blvd
Rathbun Creek
Moonridge Rd
Elm St
Summit Creek (East)
Snow Summit
Ski Resort
Water Boards
N
W
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Map Features
Figure 1-4 Summit Creek Subwatershed

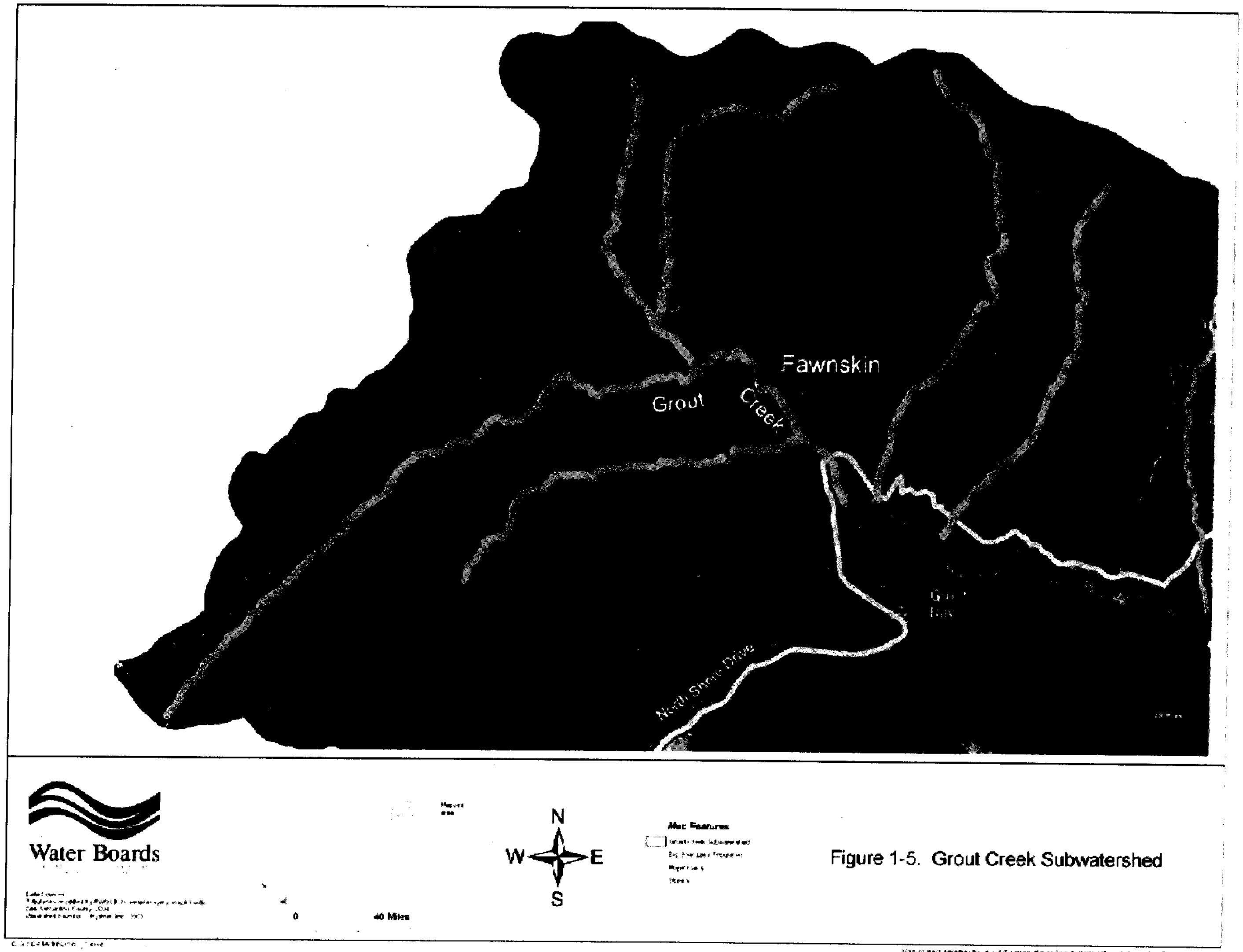

Figure 1-5. Grout Creek Subwatershed

Figure 1-6: Mean annual precipitation for the Big Bear Lake watershed (source: BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003)

Figure 1-7 shows annual precipitation amounts, in inches per calendar year, measured at Bear Valley Dam. These annual numbers do not include snowfall, which does occur at this elevation. Most precipitation occurs from December through March, as indicated by monthly precipitation averages. Over a period of 56 years, the wettest year observed was in 1969 (Figure 1-7). Since the inception of the TMDL Task Force's[1] monitoring program (2001), recorded precipitation levels have been low. Consequently, lake levels, which are dependent upon surface runoff and direct precipitation, have also been extremely low (Figure 1-8).

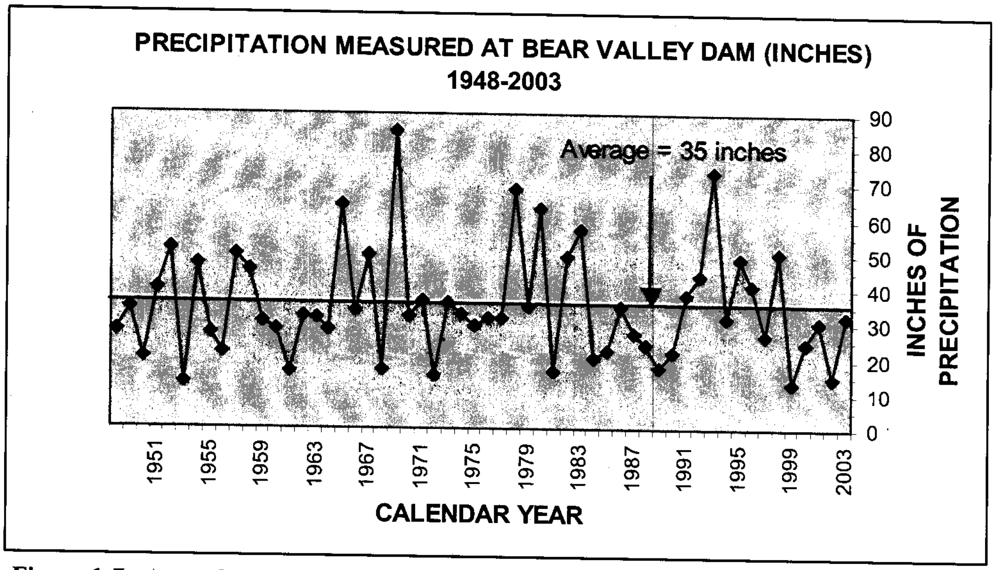

Figure 1-7. Annual precipitation, in inches, measured at Bear Valley Dam (Source: BBMWD 2004b)

[1] The TMDL Task Force was created by the Big Bear Municipal Water District in 2000. It consists of a number of local agencies and private interest groups including: the City of Big Bear Lake; San Bernardino County Flood Control District (SBCFCD); Big Bear Area Regional Wastewater Agency (BBARWA); and Regional Board staff; Caltrans; Big Bear Mountain Resorts; the USFS; and others. BBMWD, acting on behalf of the Big Bear TMDL Task Force, has hired Tim Moore of Risk Sciences, Inc., as a consultant to develop and execute the appropriate studies to support TMDL development and to secure funding sources for the needed studies. The Task Force budget was created by a partnership of the BBMWD, the City of Big Bear Lake, SBCFCD, and BBARWA.

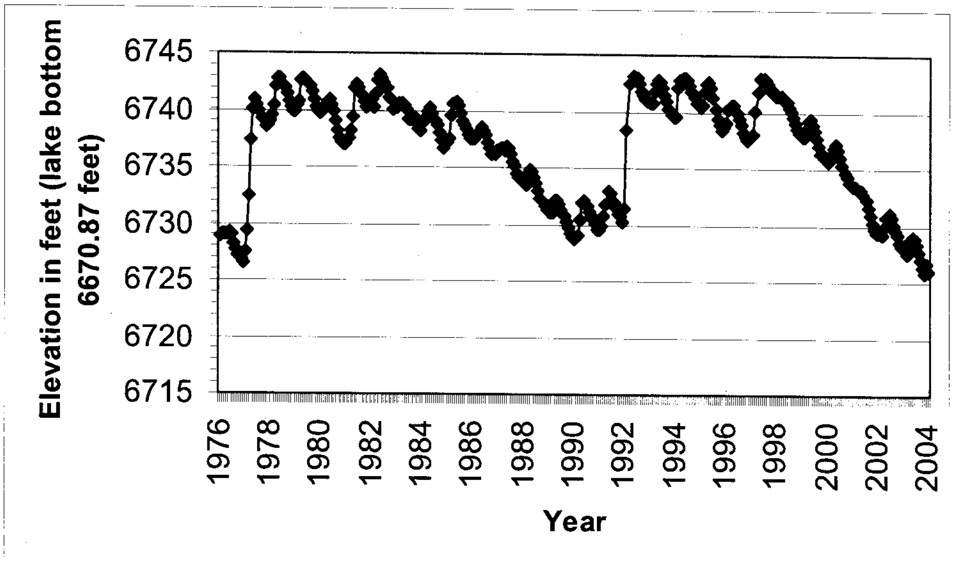

Figure 1-8: Lake elevation (in feet) for the period of record 1977- 2004 (full pool at 6743.2 feet) (Source: BBMWD 2004a)

Wastewater. Big Bear Area Regional Wastewater Agency (BBARWA), a joint powers authority created in 1974, provides interceptor service, secondary treatment and disposal by reclamation of all collected municipal wastewater in the Big Bear Valley (Engineering Resources of Southern California 1998, 1). The agency is located in Big Bear City and all the treated wastewater is disposed of in Lucerne Valley (Engineering Resources of Southern California 1998, 2). The sewerage system was installed in response to a prohibition on the use of subsurface disposal systems adopted by the Regional Board in 1973; there are limited exemptions to the prohibition, largely applicable to developments on large parcels outside existing sewer service area boundaries.

Land Use. The USFS is the largest landowner in the Big Bear area. The two ski resorts, Bear Mountain and Snow Summit, operate under special use permits from the USFS. Bear Mountain ski resort has 748 total permit acres; of that total, 198 acres are developed with 34 trails. The remaining acreage (550 acres) is undeveloped land that includes Deer, Goldmine and Bow Canyons (Bear Mountain Resort 2003). Snow Summit ski resort, built in 1952, is 620 acres in size, with 230 skiable acres (City of Big Bear Lake 1999, ER-24, OPR-6). Snow Summit is also used for mountain biking during the summer. A third abandoned ski resort, Snow Forest, is located to the southwest of Knickerbocker Creek. The San Bernardino Recreation Club and the Big Bear Lake Park District opened this area to skiing and tobogganing in 1939 (City of Big Bear Lake 1999, ER-24). This site is a contributor of sediment and potentially nutrients to Big Bear Lake.

The only incorporated city in the Big Bear Lake watershed is the City of Big Bear Lake, which was incorporated in 1980. The permanent population of the City of Big Bear Lake in 1980 was 4,923 and 6,049 in 1998. Of a total of 9,019 dwelling units in the City as of January 1, 1998, only 26% were permanently occupied. An estimated 50,000 or more people visit the City of Big

Bear Lake on a peak holiday weekend and the U.S. Forest Service estimates 5 million people visit Big Bear Valley each year (City of Big Bear Lake 1999, LU-4, LU-6).
A total of 4,466 acres are currently in the City of Big Bear Lake planning area and are designated for a variety of land uses, including residential, commercial, and industrial. The southern boundary of the City of Big Bear Lake's sphere of influence follows the USFS' boundary (City of Big Bear Lake 1999, LU-3) (see Figure 1-1).

For modeling purposes, the Big Bear Lake watershed was delineated using the watershed boundaries from CalWater v. 2.2 and incorporated the Hydrologic Subarea Boundary (HSA) of Bear Valley (801.71). Further refinement of the watershed boundary was obtained using the USGS 7.5 Minute Quadrangle sheets (Fawnskin, Moonridge, Big Bear Lake, and Big Bear City). The watershed was then further divided into 83 subbasins (Figure 1-9) to permit the greatest flexibility in simulating watershed processes. The subbasins were delineated based on topographic features, stream reaches, and the storm water system Geographical Information System (GIS) files supplied by the City of Big Bear Lake. The Rathbun Creek, Grout Creek, and Summit Creek subwatersheds consist of subbasins 31-46; 3-6; and 48-50, respectively, as shown in Figure 1-9.

Utilizing GIS analysis, the areas of various types of land use within the watershed were determined (Table 1-2 and Figure 1-10). These land uses were also used for the Hydrological Simulation Program Fortran (HSPF) model development (see Section 4.0). Land use layers consisted of 1996 aerial photos from the USGS and the City of Big Bear Lake's current (2002) zoning map. The following ratios were used to determine the percentage of impervious/pervious area for each land use: forest north (0.5%/99.5%); forest south (0.5%/99.5%); resort (5%/95%); residential (15%/85%); and high density urban (50%/50%)[2]. The majority of the land use area in the Big Bear Lake watershed is still pervious. The predominant land use in the watershed is forest (62.7%). The resort land use designation includes the ski resorts, parks and golf courses. The historic ski resort, Snow Forest, near Knickerbocker Creek, was also included in the resort land use category. High density urban includes commercial, industrial and multiple family land uses (BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003).

[2] The nomenclature "Forest North" and "Forest South" refer to the topographic aspect, not to whether the forest is located to the north or south of the lake. Distinctions in topographic aspects were important to the HSPF modeling effort because of the effect of snow accumulation and snowmelt on water resources. North facing slopes accumulate more snow and melt slower than do south facing slopes.

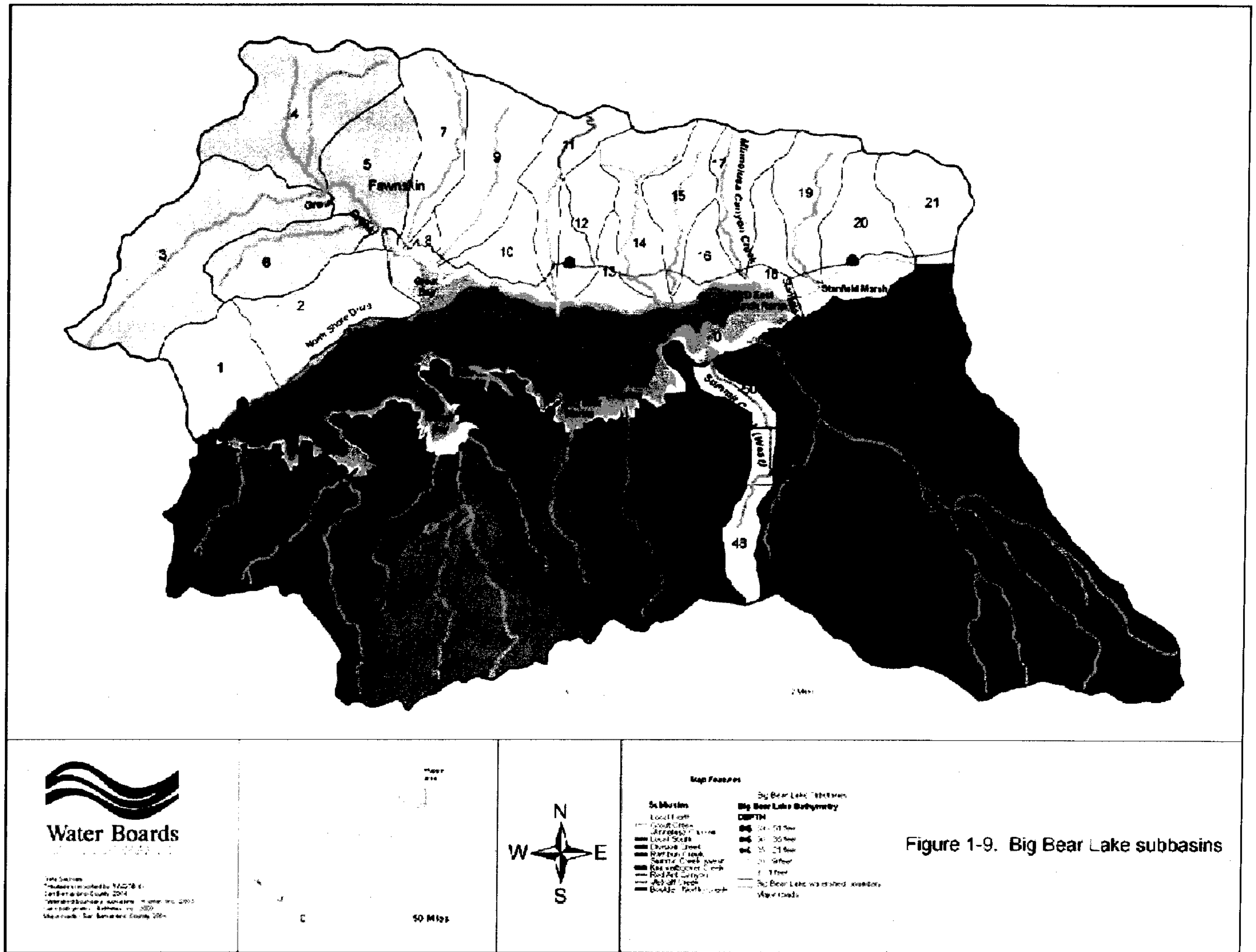

Figure 1-9. Big Bear Lake subbasins

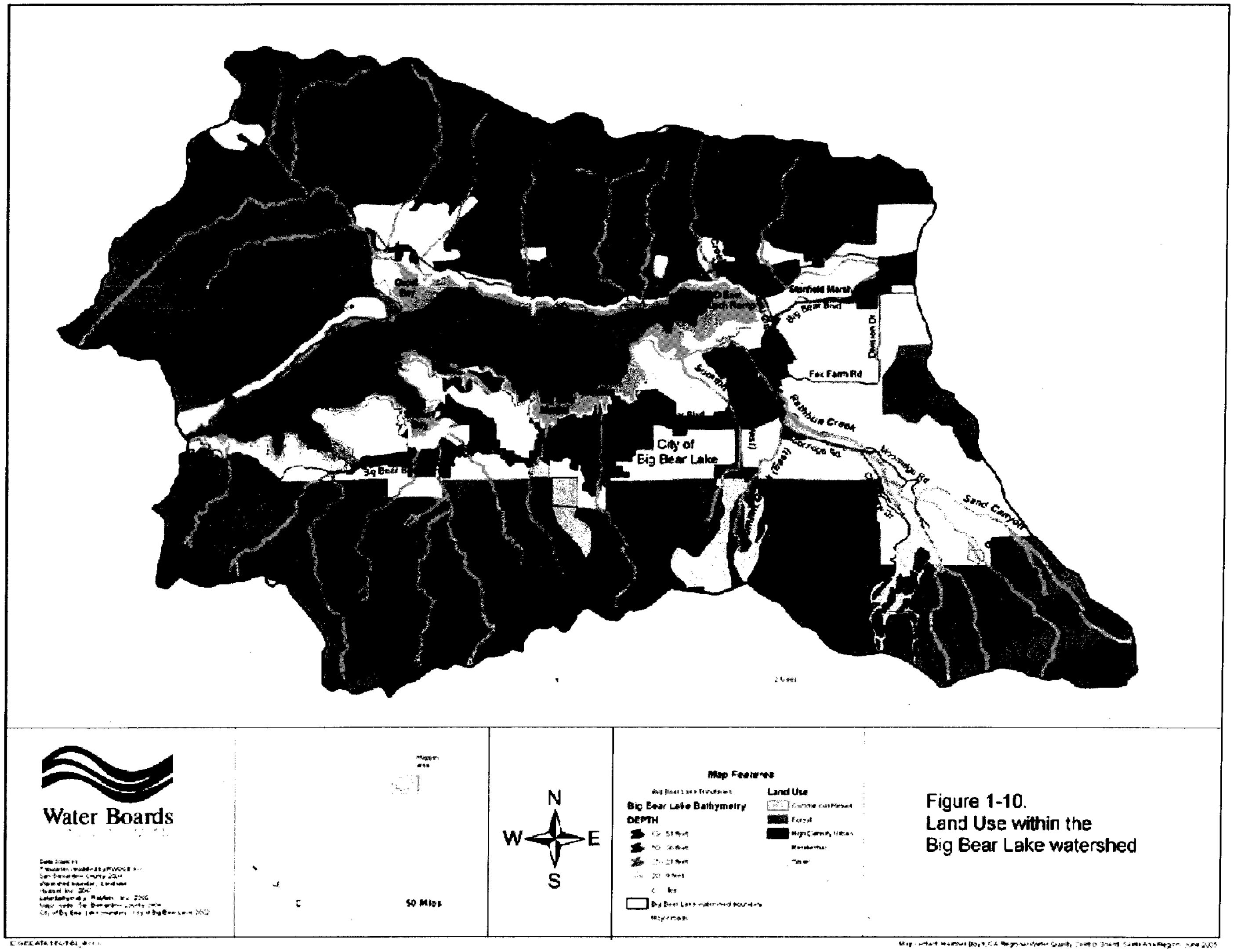

Figure 1-10.
Land Use within the
Big Bear Lake watershed

Table 1-2. Impervious and Pervious land use distribution in the Big Bear Lake watershed

	AREA (acres)			
Major Land Use Type	**Impervious**	**Pervious**	**Total**	**Percentage of Watershed (%)**
Forest North	38	7595	7,633	32.9
Forest South	35	6876	6,911	29.8
Resort	35	669	704	3.0
Residential	580	3287	3,867	16.7
High Density Urban	644	644	1,288	5.5
Big Bear Lake	-	-	2,808	12.1
Total Watershed	1,332	19,071	23,211	100

Note: Forest North and Forest South refer to the aspect, not to whether the forest is located to the north or south of the lake.
Source: Modified from Hydmet, Inc. 2004

Shown in Table 1-3, are the pervious and impervious land use distributions for Rathbun Creek, Summit Creek, and Grout Creek. The percentages of impervious/pervious land use identified for the watershed as a whole were also used for these subwatersheds. The predominant land use in all three of the subwatersheds is forest; Grout Creek subwatershed is >96% forest. Both the Rathbun Creek and Summit Creek subwatersheds include ski resorts as one land use category. The most urbanized of these three subwatersheds is Summit Creek.

Table 1-3. Impervious and pervious land use distribution in the Rathbun Creek, Summit Creek, and Grout Creek subwatersheds

	AREA (acres)			
Major Land Use Type	**Impervious**	**Pervious**	**Total**	**Percentage of Subwatershed (%)**
Rathbun Creek				
Forest North	10	1991	2001	49
Forest South	2	434	436	11
Resort	9	417	426	10
Residential	151	856	1007	25
High Density Urban	110	110	220	5
Total subwatershed	282	3808	4090	100
Summit Creek				
Forest North	0	56	56	16
Forest South	0	9	9	3
Resort	5	101	106	30
Residential	17	95	112	32
High Density Urban	33.5	33.5	67	19
Total subwatershed	55.5	294.5	350	100
Grout Creek				
Forest North	6	1205	1211	42
Forest South	8	1565	1573	54
Resort	0	0	0	0
Residential	16	88	104	3.6
High Density Urban	7.5	7.5	15	0.5
Total subwatershed	37.5	2865.5	2903	100.1

Note: Forest North and Forest South refer to the aspect, not to whether the area is located to the north or south of the lake
Source: Modified from Hydmet, Inc. 2004

Fish and Wildlife. There are two fisheries in Big Bear Lake, a warm water fishery consisting of centrarchids (largemouth bass, bluegill and pumpkinseed) and channel catfish, and a cold water fishery with frequent stocking of rainbow trout. In addition, there are large populations of carp present in the lake. The three centrarchids, members of the Sunfish family (Family taxon Centrarchidae), spawn at different water temperatures. The largemouth bass spawns in the early spring when water temperatures are at 14-16° C, the bluegill spawns when water temperatures are at about 18-21° C, and the pumpkinseed spawns when water temperatures are at about 20° C. These fish have different dietary and habitat preferences as well. The pumpkinseed prefer damselfly naiads and gastropods and prefer the dense macrophyte beds. The bluegill's diet consists of zooplankton, damselfly naiads, and chironomids and they prefer the fringe of the weed beds. The largemouth bass' diet consists of chironomids, crayfish and fish.

The bass also prefer the fringe of the weed beds but select larger prey than the bluegill (Siegfried et al. 1978, 49-50). Half-pound Rainbow trout from the Mojave Fish Hatchery are stocked in Big Bear Lake twice a month from April to November, with a 36,000 lb allotment per calendar year. One-hundred fifty thousand subcatchables are also stocked per year. These smaller, 6-inch rainbow trout are an Eagle Lake trout strain (Uplinger 2000). According to the Big Bear Municipal Water District (2002a), there are 9 species of fish in the lake (Largemouth bass, smallmouth bass, silver salmon, bluegill, pumpkinseed, crappie, catfish, carp and rainbow trout). Because of these habitat and dietary differences, it is important that the aquatic plant community in the lake consist of a variety of species and that no one species forms a monoculture, as Eurasian watermilfoil has essentially done in Big Bear Lake (Section 2.0). A diverse aquatic plant community is necessary to support the diversity of fish and other wildlife species. The development of monocultures threatens the diversity of the biota.

Rare/Threatened/Endangered Species. Bald eagles winter at Big Bear Lake and adjacent Baldwin Lake. In 1998, there were approximately 15 to 28 bald eagles. The eagles perch in trees within wooded areas along the southern lakeshore, around Metcalf Bay and Eagle Point, and along the eastern shore of the lake. They also forage on fish within Big Bear Lake. Any outdoor activity that could disturb the eagles should be restricted from December 1 through April 1 (City of Big Bear Lake 1999, ER-5, ER-6).

2.0 PROBLEM STATEMENT

Eutrophication is a natural progression of nutrient enrichment and basin filling that lakes and reservoirs experience. Without human-induced or "cultural" eutrophication, lakes naturally take thousands of years to progress from an oligotrophic condition, in which the water is clear, but nutrient-poor, to an eutrophic condition, in which the water is less clear, but nutrient-rich. Eutrophy is characterized by excessive nutrients, proliferation of plant growth (phytoplankton[3], periphyton[4] and macrophytes[5]), an anaerobic hypolimnion[6] during the summer, poor transparency and domination of bottom-dwelling fish (e.g., carp).

Historical studies and data have indicated that Big Bear Lake is eutrophic (Pearson and Irwin 1972, 1, 17; Irwin and Lemons 1974, 1, 36-39; Siegfried et al. 1978, 55-60; Siegfried and Herrgesell 1979a, 1-2, 24-28; Courtier and Smythe 1994). The researchers noted that both internal recycling of nutrients from sediments and nonpoint source loading to the lake must be reduced to improve Big Bear Lake's trophic state. Leidy's (2003a) report offers an alternative hypothesis on the origin of eutrophic conditions in Big Bear Lake. The report contends that the lake was always eutrophic and that the conditions presently seen are not due to anthropogenic activities, but simply represent surplus nutrient loadings due to the fact that the area in which the Bear Valley Reservoir, and subsequently Big Bear Lake were sited was already nutrient-enriched (36).

Nitrogen and phosphorus are essential to the growth of plants and animals. However, in large amounts these nutrients can result in stimulation of excessive growth of macrophytes and algae, resulting in physical, chemical and biological changes that in turn affect the nature and abundance of the animal community. The following paragraphs discuss macrophytes, algae and the nitrogen and phosphorus cycles.

Macrophytes. Macrophytes are any macroscopic form of aquatic plant life and include Eurasian watermilfoil and coontail (Wetzel 2001, 528). Aquatic macrophytes can be either attached to the substrate (e.g., Eurasian watermilfoil) or not rooted and freely floating (e.g., coontail). Attached forms include emergent macrophytes[7], floating-leaved macrophytes[8] and submersed macrophytes[9]. Most freely floating macrophytes are confined to protected areas such as bays, where they absorb nutrients through the water column and are usually an indication of nutrient rich waters (Wetzel 2001, 531). Most submersed macrophytes are usually found in water depths greater than 1 meter because wave exposure is lessened and sediment stability is increased (Wetzel 2001, 541).

Macrophytes are an important part of the aquatic ecosystem, providing cover, nursery and foraging habitat for fish and other wildlife. Macrophytes also provide erosion control by protecting and stabilizing the shoreline. Macrophyte growth is controlled by a variety of factors, including temperature, light, and sediment type. The rooted macrophytes are restricted to the

---

[3] Phytoplankton are floating, microscopic algae.
[4] Periphyton are organisms that grow on underwater surfaces.
[5] Macrophytes are any macroscopic form of aquatic plant life (Wetzel 2000, 528).
[6] The hypolimnion is the bottom layer of a thermally stratified lake and is characterized by cold and unmixed waters.
[7] Emergent macrophytes occur in soils where the water table is approximately 0.5 m below the soil surface up to water depths of 1.5 m (include bulrushes *(Scirpus)* and cattails *(Typha)*) (Wetzel 2001, 529)
[8] Floating-leaved macrophytes occur attached to sediments at water depths from 0.5 m to 3 m and include water lilies and pondweed *(Potamogeton)* (Wetzel 2001, 529)
[9] Submersed macrophytes occur at all depths within the photic zone (includes Eurasian watermilfoil)

littoral zone[10] due to limits on light penetration. Rooted macrophytes obtain the majority of their nutrients from the sediment, while epiphytic algae[11] attached to the macrophytes uptake nutrients from the water column. The rooted macrophytes "pump" nutrients from the sediments into their tissues. During macrophyte growth and decomposition, nutrients can be released from the plant tissues into the water column, but most of the nutrients released by the macrophytes is sequestered by the attached algae and recycled (Wetzel 2001, 549).

Algae. Algae, like macrophytes, need light and nutrients to grow. If turbidity is high, if there are macrophytes present, or if there is already an abundance of algae present in the lake, then algae growth will be limited by light. If the nutrient necessary for algae growth is controlled, or if grazers (zooplankton[12]) are abundant, then algae growth will also become limited. Algae can be filamentous, colonial, or unicellular and are classified according to pigment composition, among other physiological characteristics (Wetzel 2001, 332-337). Blue-green algae usually are a nuisance because they form massive blooms, which lead to taste and odor problems, as well as possible toxicity. Blue-green algae also carry out nitrogen fixation (transformation of nitrogen gas to ammonia) in lakes. It is hard to control blue-green algae because nitrogen fixation provides a reliable source of nitrogen.

Phytoplankton usually follow a seasonal succession whereby diatoms and sometimes golden algae are prevalent in spring, followed by green algae in late spring and early summer, and then blue-green algae in summer. If the lake turns over in the fall (i.e., lake mixes from top to bottom caused by cooling waters and wind), there is oftentimes a short-lived bloom of diatoms, blue-green algae, or dinoflagellates (Wetzel 2001, 358).

Nitrogen and Phosphorus Cycles. Runoff from the watershed results in the addition of nitrogen and phosphorus to surface waters. Inorganic nitrogen is transported in surface water runoff in both the dissolved and particulate forms. Groundwater inflow is also an avenue of transport of dissolved inorganic nitrogen. Atmospheric deposition adds nitrogen to surface waters. Nitrogen is abundant as nitrogen gas, but to be usable to plants and animals, it must first be converted to nitrate and other usable forms through the nitrogen cycle processes (USEPA 1999). These processes are detailed in the following paragraph.

The nitrogen cycle consists of nitrogen fixation, ammonification, nitrification, and denitrification. Nitrogen-fixing organisms, such as blue-green algae, convert nitrogen gas into un-ionized and ionized ammonia. Nitrogen fixation can comprise a large percentage of the annual total nitrogen inputs (> 80%) in an eutrophic or hypereutrophic lake with high phosphorus loadings and no phosphorus limitations on blue-green algae growth (Wetzel 2001, 209). Ammonification occurs when amino acids, a product of the decomposition of wastes and organic tissues by decomposer organisms, are oxidized to ammonia ions, water, and carbon dioxide (USEPA 1999). Nitrification is a two-step process involving two different sets of microorganisms. In the first step, *Nitrosomonas* microorganisms oxidize ammonia ions to nitrite and water. These bacteria can tolerate temperature ranges of 1-37° C and grow optimally at pH 7 (Wetzel 2001, 216). In the second step, *Nitrobacter* microorganisms oxidize the nitrite ions to nitrate. These bacteria are less tolerant of low temperatures and high pH (Wetzel 2001, 216). Nitrate must be converted to

[10] The littoral zone is the area from the shoreline region between the highest and lowest seasonal water levels to the greatest depth at which rooted plants occur (Wetzel 2001, 131-132).
[11] Algae that grow on macrophytes.
[12] Zooplankton are microscopic animals that feed on algae and are consumed by fish.

ammonium by nitrate reductase before it is in the bioavailable form. Through denitrification, nitrates are reduced to gaseous nitrogen by facultative anaerobes[13] (USEPA 1999).

Phosphorus is not abundant in the aquatic environment under natural conditions and is usually the nutrient limiting biological productivity[14]. Orthophosphate is the most important form of inorganic phosphorus because it can be used directly by algae. Soluble reactive phosphorus (SRP) includes orthophosphate. Total phosphorus is the measurement of both organic and particulate forms (which are not bioavailable) and soluble reactive phosphorus (which is bioavailable). A large percentage of phosphorus in fresh waters is in the organic phase (Wetzel 2001, 241). Organic phosphorus is converted to phosphate in the sediments primarily by the break down of organic matter by bacteria.

Phosphorus sorbs to soil particles and organic matter and is transported to surface waters via eroded sediments. Phosphorus can become unavailable as it sorbs to particles and the bottom substrate of lakes and reservoirs. As the bottom layer of a lake or reservoir becomes anoxic, phosphorus can desorb from sediments and recycle back into the water column. Also, bottom dwellers such as carp can disturb the bottom layer, causing phosphorus to be released from the sediments into the water column. Algae, including both microscopic and attached forms, and bacteria take up soluble reactive phosphorus, mainly as orthophosphate, and convert it to organic phosphorus. These algae and bacteria are in turn consumed by zooplankton, which excrete some of the organic phosphorus as SRP. Plants and animals then take in the SRP and the cycle begins again (USEPA 1999).

Phosphorus is deposited in lake bottom sediments via five different pathways: sedimentation of phosphorus minerals transported from the surrounding watershed; adsorption or precipitation of phosphorus with inorganic compounds; allochthonous[15] organic matter sedimentation of phosphorus; autochthonous[16] organic matter sedimentation of phosphorus; and, algal and macrophyte uptake of phosphorus from the water column and subsequent deposition to the sediments as detritus (Wetzel 2001, 245-246).

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[13] Organisms that can live in the presence or absence of oxygen.

[14] The limiting nutrient is usually nitrogen or phosphorus and it is the nutrient that when not available in sufficient quantities limits plant growth. A ratio of nitrogen to phosphorus of less than 7:1 in water is usually nitrogen limited and ratios greater than 10:1 are indicative of phosphorus limited water bodies (USEPA 2000b).

[15] Organic matter created within the watershed and imported to the water body (Wetzel 2001, 49)

[16] Organic matter created within the water body (Wetzel 2001, 49)

The following sections (Sections 2.1-2.2) outline the applicable water quality standards and evaluate the data that were used to place Big Bear Lake on the 1994 303(d) list for nutrients and noxious aquatic plants. Creek data are discussed separately and are contained in Appendix A. Additional data that were collected after Big Bear Lake was placed on the 1994 303(d) list are also evaluated. Finally, a new set of data was collected beginning in 2001 as part of the TMDL Task Force monitoring. Although there were extensive nutrient data already present and BBMWD regularly collected nutrient samples and depth profiles, there were data gaps that needed to be filled. These gaps arose in part because of the varying analytical methods and detection limits, analytes and sampling locations that had been used in the various investigations of lake and tributary water quality conducted to that time. These variations made data comparison and interpretation difficult. It was recognized that there was a need to collect phosphorus data utilizing lower detection limits, to analyze for ammonium, orthophosphate, and chlorophyll *a* on a regular basis, and to collect data from representative areas within Big Bear Lake and the watershed at a regular interval. These data are also evaluated and compared to the applicable water quality standards.

2.1 Applicable Water Quality Standards

The beneficial uses of Big Bear Lake as identified in the 1995 Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) are as follows:

- Municipal and Domestic Supply **(MUN)**
- Agricultural Supply **(AGR)**
- Groundwater Recharge **(GWR)**
- Water Contact Recreation **(REC1)**
- Non-contact Water Recreation **(REC2)**
- Warm Freshwater Habitat **(WARM)**
- Cold Freshwater Habitat **(COLD)**
- Wildlife Habitat **(WILD)**
- Rare, Threatened or Endangered Species **(RARE)**

The beneficial uses of Rathbun Creek as identified in the Basin Plan are as follows:

- Municipal and Domestic Supply **(MUN)**
- Groundwater Recharge **(GWR)**
- Water Contact Recreation **(REC1)**
- Non-contact Water Recreation **(REC2)**
- Cold Freshwater Habitat **(COLD)**
- Wildlife Habitat **(WILD)**

The beneficial uses for Grout Creek as identified in the Basin Plan are as follows:

- Municipal and Domestic Supply **(MUN)**
- Groundwater Recharge **(GWR)**
- Water Contact Recreation **(REC1)**
- Non-contact Water Recreation **(REC2)**
- Cold Freshwater Habitat **(COLD)**
- Wildlife Habitat **(WILD)**
- Spawning, Reproduction, and Development **(SPWN)**

The beneficial uses for Summit Creek as identified in the Basin Plan are as follows (all are **intermittent** beneficial uses):

- Municipal and Domestic Supply **(MUN)**
- Groundwater Recharge **(GWR)**
- Water Contact Recreation **(REC1)**
- Non-contact Water Recreation **(REC2)**
- Cold Freshwater Habitat **(COLD)**
- Wildlife Habitat **(WILD)**

The Basin Plan specifies the following narrative and numeric water quality objectives for inland surface waters that pertain to nutrient impairment:

> Algae: "Waste discharges shall not contribute to excessive algal growth in inland surface receiving waters."
>
> Nitrate: " Nitrate-nitrogen concentrations shall not exceed 45 mg/L (as NO3) or 10 mg/L (as N) in inland surface waters designated **MUN** as a result of controllable water quality factors."
>
> Un-ionized ammonia (UIA)[17] for COLD (most restrictive):
> Acute (1-hour) objective = 0.822[0.52/FT/FPH/2]
> Chronic (4-day) objective = 0.822[0.52/FT/FPH/RATIO]
> (Please see the 1995 Basin Plan pp. 4-5 and 4-6 for an explanation of FT, FPH and RATIO)
>
> Dissolved oxygen (DO): "The dissolved oxygen content of surface waters shall not be depressed below 5 mg/L for waters designated **WARM**, or 6 mg/L for waters designated **COLD** as a result of controllable water quality factors. In addition, waste discharges shall not cause the median dissolved oxygen concentration to fall below 85% of saturation or the 95th percentile concentration to fall below 75% of saturation within a 30-day period."

[17] The UIA objectives specified in the Basin Plan have not been approved by the USEPA. The USEPA recommends that these objectives be reviewed and revised based on the USEPA's revised national ammonia criteria. A review of the UIA objectives was included on the Regional Board's 2002 Triennial Review list.

The Basin Plan also specifies site-specific nutrient numerical water quality objectives for Big Bear Lake. These are as follows:

- Total phosphorus -- 150 μg/L
- Total inorganic nitrogen (TIN) [18] -- 150 μg/L

No site-specific numeric nutrient objectives have been established for the Big Bear Lake tributaries.[19]

2.2 Assessment of Existing Conditions Relative to Numeric and Narrative Water Quality Objectives

This section describes conditions in the Big Bear Lake watershed that resulted in the inclusion of Big Bear Lake as nutrient impaired on the 1994 303(d) list (Table 2-1). Nutrient data that were evaluated and compared to the objectives for Big Bear Lake as part of the initial TMDL problem identification were the data collected in 1994 by the Regional Board as a follow-up to the Clean Lakes Study (Table 2-2), data collected from 1994-2000 by the BBMWD (Table 2-3), and data collected from 2001-2003 by the TMDL Task Force (Table 2-4). For all datasets, Big Bear Lake data are compared to the Basin Plan Objectives specified above. Data that exceed the Basin Plan Objectives are noted in the respective table for each dataset. See Appendix A for tabulation of creek data.

Total Phosphorus, TIN, Nitrate as N, Un-ionized ammonia. The nutrient-related data used to place Big Bear Lake on the 1994 303(d) list were collected as part of a Clean Water Act Section 314 grant (Clean Lakes Study) titled, "Investigation of Toxics and Nutrients in Big Bear Lake." (Courtier and Smythe 1994). The data were collected between April 1992 and April 1993 (Table 2-1).

Table 2-1. Nutrient concentrations (μg/L) for Big Bear Lake (April 1992-April 1993)

	Total P	**Total N**	**TIN***	**UIA-N (chronic)**	**NO3-N**
Average	47	1220	236	NA	66
Median	40	1250	100	NA	23
Number of samples	18	18	18	18	18
Number of non-detects	2	0	NP	NA	13
Max	120	2200	650	NA	470
Basin Plan Objective	**150**	**NA**	**150**	**Varies with pH/Temp**	**10**
Number of samples equal to, or exceeding BP Objective	0(0%)	NA	4(22%)	4(22%)	0(0%)

One-half of the detection limit for non-detects was used to calculate the descriptive statistics
*TIN is calculated from the sum of nitrate, nitrite and ammonia individual values
NA = not applicable
NP = no detection limit provided

[18] TIN is the sum of nitrate, nitrite, and ammonia forms of nitrogen. Staff believes that total nitrogen rather than TIN is the parameter of concern (See Section 3.0, Numeric Targets for detailed discussion).
[19] The numeric objectives specific to Big Bear Lake do not apply to the lake's tributaries via the tributary rule, only the narrative objectives specified in the Basin Plan apply (Vassey 2004).

Data from 1994 were also used to assess nutrient quality in the lake. Data for Big Bear Lake are compared to the Basin Plan Objectives and values that exceed those objectives are shown in Table 2-2.

Table 2-2. Nutrient concentrations (µg/L) for Big Bear Lake (May 1994)

	Total P	Total N	TIN*	UIA-N (chronic)	NO3-N**
Average	43	1333	756	NA	--
Median	40	1450	725	NA	--
Number of samples	4	4	4	4	4
Number of non-detects	0	0	NP	NA	4
Max	70	1800	1525	NA	--
Basin Plan Objective	**150**	**NA**	**150**	**Varies with pH/Temp**	**10**
Number of samples equal to, or exceeding BP Objective	0(0%)	NA	3(75%)	2(50%)	0(0%)

*TIN is calculated from the sum of nitrate, nitrite and ammonia individual values.
** Statistics not provided as all samples were non-detect
NA = not applicable
NP = no detection limit provided

Data collected by the BBMWD from 1994-2000 were also evaluated against the TP, TIN, nitrate and un-ionized ammonia chronic objectives in the Basin Plan (Table 2-3).

Table 2-3. Nutrient concentrations (µg/L) for Big Bear Lake (BBMWD:1994-2000)

	Total P	Total N	TIN*	UIA-N (chronic)	NO3-N**
Average	37	818	10	NA	--
Median	25	800	0	NA	--
Number of samples	144	178	178	24	104
Number of non-detects	135	1	NP	23	104
Max	750	1800	500	NA	--
Basin Plan Objective	**150**	**NA**	**150**	**Varies with pH/Temp**	**10**
Number of samples equal to, or exceeding BP Objective	3(2%)	NA	3(2%)	NC	0(0%)

One-half of the detection limit for non-detects was used to calculate the descriptive statistics.
*Only 11 samples out of 178 had a concentration above 0 µg/L. TIN was calculated as the difference between TN and TKN (ammonia was below detection limits).
**Statistics not provided as all samples were non-detect.
NA = not applicable
NP = no detection limit provided
NC = not calculated because temperature was not recorded

TMDL Monitoring Program

Starting in June 2001, a program of monthly nutrient monitoring at four main lake stations and seven tributary stations was initiated as part of the nutrient Total Maximum Daily Load (TMDL) process and is presently ongoing. Originally, ten lake stations were monitored but after February 2002, only four main lake stations (Dam (#1), Gilner Point (#2), Mid Lake Middle (#6), and Stanfield Middle (#9)) or MWDL1, MWDL2, MWDL6, and MWDL9 were monitored due to limited funds (Figure 2-1). Data from June 2001 through Oct. 2003 is included in the analysis for these four main TMDL stations (Table 2-4). At all ten stations a photic zone[20] composite water column sample and a discrete bottom water column sample were analyzed for total nitrogen, total dissolved nitrogen, ammonia-N, nitrate + nitrite-N, total phosphorus, total dissolved phosphorus and orthophosphate-P. Chlorophyll *a* was analyzed in the photic zone composite samples since algae need light to grow. As shown in Table 2-4, these data were evaluated against the nutrient objectives. Please refer to Appendix A for tributary data summaries.

[20] Photic zone is the zone to which light can penetrate the water column. For the purposes of this monitoring, the photic zone is calculated as two times the secchi depth.

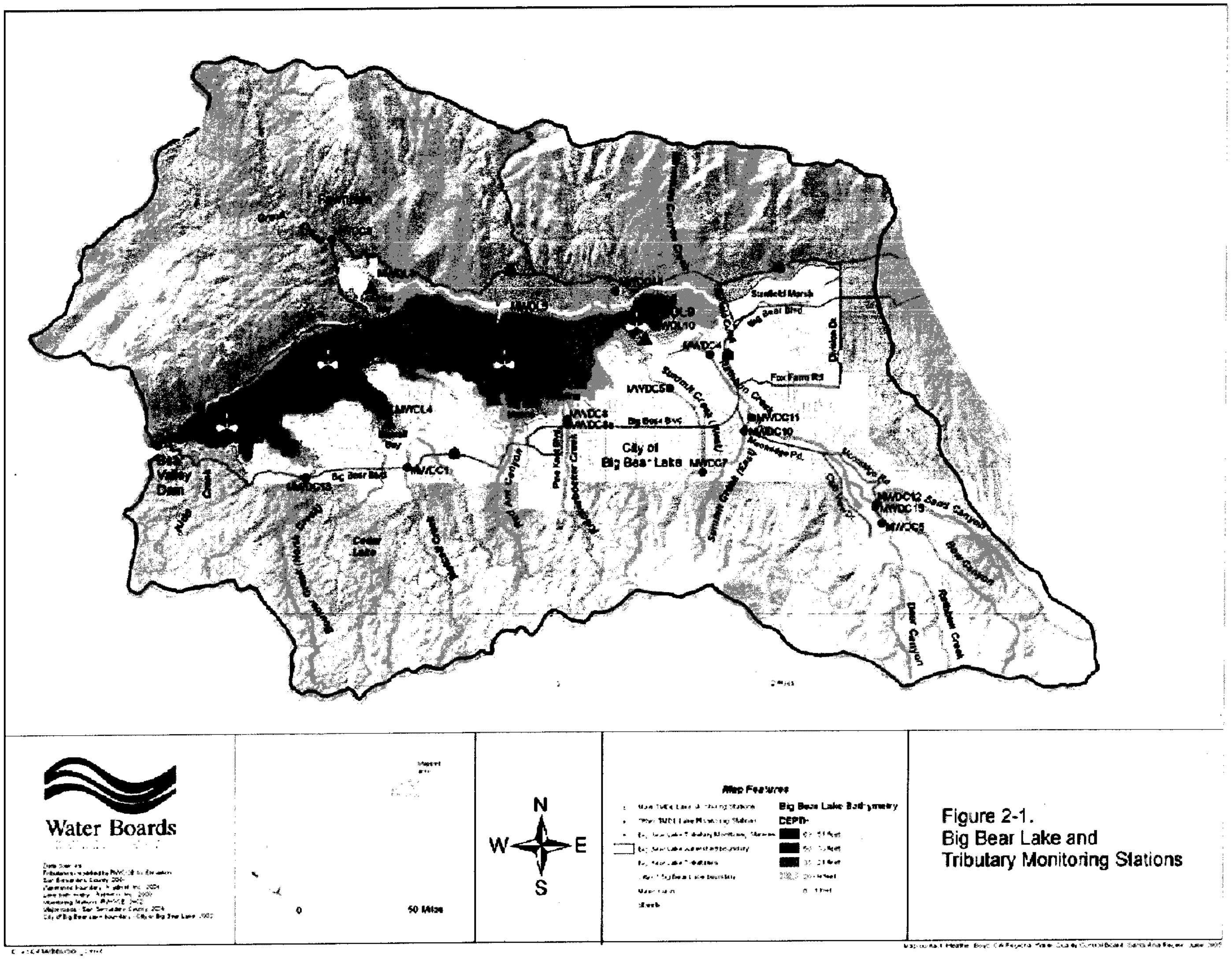

Figure 2-1.
Big Bear Lake and
Tributary Monitoring Stations

Table 2-4. Big Bear Lake nutrient water quality data summary (June 2001- October 2003)

	Ortho-P	**Total P**	**Total Dissolved P**	**Total N**	**Total Dissolved N**	**Nitrate+Nitrite as N**	**Ammonia as N**	**Chlorophyll a**	**TIN**	**UIA-N (chronic)**
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/m^3	µg/L	
Minimum	0.2*	8	6	883	756	0.1*	4	1.5	4	--
Maximum	113	182	118	2211	1490	57	586	96.7	593	--
Median	5*	54	20	1210	959	4*	38	15.3	47	--
Mean	9*	61	24	1259	988	9*	74	17.6	82	--
Std. Dev.	14*	35	16	243	140	12*	94	13.9	95	--
25th percentile	2*	37	16	1061	893	2*	17	9.9	18	--
75th percentile	9*	71	26	1413	1070	10*	87	21.8	107	--
# of data points	250	250	249	250	249	250	250	126	250	250
Detection Limit	3	2	2	4	4	5	3	2.0	--	--
Basin Plan Objective	**NA**	**150**	**NA**	**NA**	**NA**	**10****	**NA**	**NA**	**150**	**Varies with pH/Temp**
Number of samples equal to, or exceeding BP Objective	NA	9(4%)	NA	NA	NA	0(0%)	NA	NA	35(14%)	5(2%)

TIN = Total inorganic nitrogen – calculated by summing the individual values of ammonia and nitrate+nitrite, no detection limit provided -- note that the TIN summary statistics do not equal the sum of the nitrate+ nitrite as N and ammonia as N summary statistics because all summary statistics were based on individual values (e.g., the max nitrate + nitrite as N and max ammonia as N did not occur on the same sampling date, so the max TIN does not equal the sum of these two maximum values).
NA = Not applicable
Statistics not calculated for UIA-N (chronic).
* Estimated using both the robust probability plotting method and by the (parametric) maximum likelihood method adjusted for bias (Helsel and Cohn 1988).
**Note that the Basin Plan Objective is for Nitrate-N.

Noxious aquatic plants. Big Bear Lake was also identified on the 1994 303(d) list as impaired due to noxious aquatic plants. Big Bear Lake is eutrophic, as demonstrated by the proliferation of nuisance aquatic plants, primarily Eurasian Watermilfoil (*Myriophyllum spicatum* L.) and Coontail (*Ceratophyllum demersum* L.). Eurasian watermilfoil is listed as a state noxious weed in several states, including California (USDA 2003). Eurasian watermilfoil is a rooted submersed plant, found in waters from 1 to 15 feet in depth. As stems reach the water surface, they branch out and form dense canopies that shade out other vegetation. It is a perennial that overwinters by root crown and is spread by runners and fragments (Aquatic Plant Management Society 2002b; USCOE 2002). Coontail is a submersed free-floating (rootless) plant, found in waters 1-20 feet deep. It provides an important habitat for aquatic organisms and is found in standing water. It is an evergreen perennial and a prolific seed former. Coontail is usually not considered a major nuisance plant. However, in certain habitats it can become the dominant species, crowding out other species. It also forms a dense mat and can affect boating and other recreational activities on the lake (Aquatic Plant Management Society 2002a; USCOE 2002).

Eurasian watermilfoil was introduced to Big Bear Lake sometime in the 1970s and since that time has become a major nuisance, impairing the beneficial uses of the lake, including contact water recreation (REC1), non-contact water recreation (REC2), warm (WARM) and cold (COLD) freshwater habitat and wildlife habitat (WILD). Through mapping, (ReMetrix 2001, 4), it was determined that approximately 781 acres of Big Bear Lake were impacted by macrophyte growth at that time, primarily by Eurasian watermilfoil. Eurasian watermilfoil can grow up to one foot per week and reach the surface from depths of over 20 feet deep, if the light conditions are suitable (ReMetrix 2001, 1). It can outcompete the more beneficial species of aquatic plants in the littoral zone of Big Bear Lake, changing the species composition, and impacting the aquatic environment. Low dissolved oxygen or anoxia may develop below the Eurasian watermilfoil canopies. Eurasian watermilfoil serves as both a sink and source of nutrients. Nutrients are taken up from the sediment by the roots and stored in the plant's tissues. As the plants age and die, nutrients are released back into the water column (Smith and Adams 1986). In addition, Eurasian watermilfoil photosynthesis can raise the pH in the water column, which allows phosphorus to be released from the sediments.

Hydroacoustic data collected by ReMetrix in 2002 and 2003 (ReMetrix 2004) and analyzed by Tetra Tech (2004a) show that the greatest density of plants in Big Bear Lake is found at depths less than 10 feet, as shown in Table 2-5. Depending on the average lake level, the average suitable plant habitat area at depths less than 10 feet ranges between 500 and 600 acres for the entire lake area (Tetra Tech 2004a). Fluctuations in lake levels affect the areas of the lake less than 10 feet in depth; thus, the area that is suitable for macrophyte growth (Figure 2-2). For example, the east end segment[21], as delineated in the WASP model (see Section 5), has more suitable area for growth in 1999 than 2003. This same effect is observed in the shallow bay segments (e.g., Metcalf Bay and Grout Bay) because these areas are much shallower than the rest of the lake. So, if the average deficit from full pool in 1999 was approximately 3 feet versus nearly 14 feet in 2003, then any areas less than 14 feet deep in 2003 would be dry and not able to support macrophyte growth. Similarly, areas that were previously too deep to support macrophyte growth in 1999 became shallower from 1999-2003 and were then able to support macrophyte growth in areas that never had any macrophytes.

[21] Ten segments were used in the WASP model effort (see Section 5).

Table 2-5. Macrophyte average percent biovolume for depth intervals in surveyed segments

Depth (feet)	Boulder Bay	Metcalf Bay	Grout Bay	Main Bay	East End	Rockwall	Papoose	Average
avg <3		40.0		80.0	60.0			60.0
avg3-4	49.0	5.7		27.8	66.5		16.0	33.0
avg4-5	67.7	60.0		11.0	72.9	34.5	18.7	44.1
avg5-6	11.8	7.7	23.7	14.0	13.8	12.2	14.9	14.0
avg6-7	6.7	5.6	5.9	13.2	0.9	15.8	16.5	9.2
avg7-8	13.7	7.8	15.8	23.6	1.0	16.4	16.8	13.6
avg8-9	14.1	8.8		9.0	1.6	10.5	18.0	10.3
avg9-10	13.5	7.2		6.2	0.4	4.9	16.7	8.2
avg10-12	11.7	3.6		1.6	0.1	2.7	7.8	4.6
avg12-15	4.7	0.5		3.3	0.1	2.1	2.7	2.2
avg15-20	0.1	0.0		2.7	0.0	0.1	0.2	0.5

Source: Modified from Tetra Tech 2004a
Note: Raw 2002, 2003 data provided by ReMetrix 2004

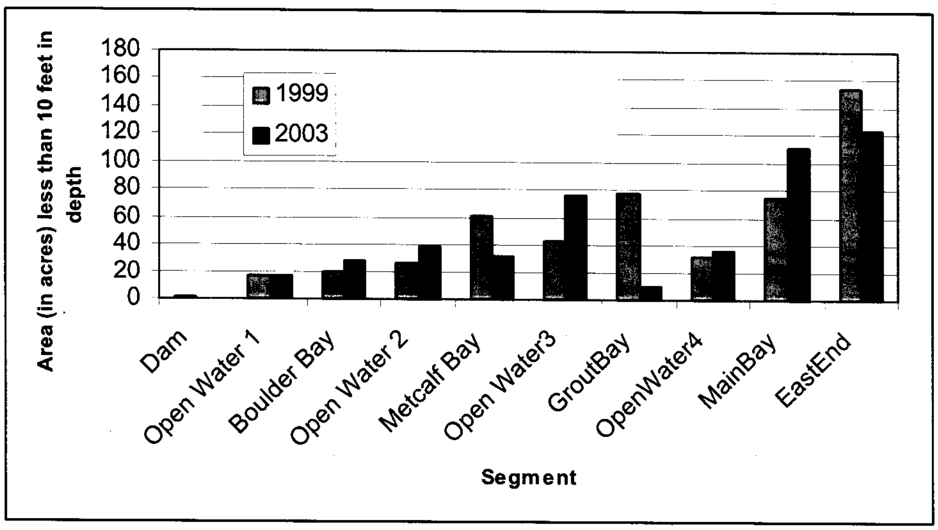

Figure 2-2: Effect of two different lake levels (1999 avg. lake level = 6740.15 feet, 2003 avg. lake level = 6729.58 feet) on macrophyte growth in areas less than 10 feet deep for the 10 segments defined in the WASP model (see Section 5) (Source: Modified from Tetra Tech 2004a)

The BBMWD has had an aquatic plant harvesting program for years, but according to recent data, harvesting is able to control only approximately 240 acres of the 781 total acres of submersed aquatic plants. In addition, because Eurasian watermilfoil grows up to one foot per week, many areas impacted by this noxious plant must be harvested more than once per season (ReMetrix 2001, 14). According to the BBMWD's records, approximately 86% of the weed cutting occurs around private docks, and the other 14% occurs where navigational hazards need to be removed or where public access needs to be improved. Eurasian watermilfoil comprises approximately 73% of all the macrophytes harvested, coontail comprises 20%, and the remaining 7% is a combination of other types (BBMWD 2002a). Shown in Figure 2-3 is a map depicting the distribution of aquatic macrophytes as observed by ReMetrix (2001). Table 2-6 is a list of all the aquatic plants that BBMWD has identified in Big Bear Lake (BBMWD 2002a).

Table 2-6. Aquatic plants present in Big Bear Lake

Common Name	Scientific Name	Type of Macrophyte
Curlyleaf pondweed	*Potamogetan crispus*	Rooted, submersed
Leafy pondweed	*Potamogetan foliosus*	Rooted, submersed
Eurasian watermilfoil	*Myriophyllum spicatum* L.	Rooted, submersed
American elodea	*Elodea canadensis*	Rooted, submersed
Coontail	*Ceratophyllum demersum* L.	Free floating, submersed
Smartweed	*Polygonum hydropiperoides* Michx.	Rooted, submersed
Sago Pondweed	*Potamogeton pectinatus* L.	Rooted, submersed
Widgeon grass	*Ruppia maritime*	Rooted, submersed
Spikerush	*Eleocharis spp.*	Emergent

Source: BBMWD 2002a

Harvesting is not a preferred control of the nuisance aquatic plants, since this approach can spread Eurasian watermilfoil fragments to other areas of the lake and can impact the bottom biota. It can also resuspend bottom sediments into the water column, contributing to the internal loading of nutrients and decreasing water clarity. Harvesting, however, also removes plant biomass, which can improve dissolved oxygen concentrations and reduce impacts to recreational and other beneficial uses. Other noxious aquatic plant removal methods besides mechanical methods include chemical, biological, and physical methods. All methods have advantages and disadvantages (Madsen 2000).

BBMWD obtained an NPDES permit in 2002 (Order No. R8-2002-0028, NPDES No. CA8000396) to apply Sonar, an aquatic herbicide, to selected parts of Big Bear Lake to aid in the eradication of Eurasion watermilfoil. BBMWD also applied Sonar again in 2003 with some funding provided by a Clean Water Act Section 319(h) nonpoint source pollution grant. Order No. R8-2002-0028 was rescinded upon adoption of Order No. R8-2004-0007 (NPDES No CA8000396), which incorporates the addition of alum as well as Sonar to Big Bear Lake.

Sonar, which contains the active ingredient fluridone, is a systemic herbicide. This means that the herbicide is absorbed by the plant leaves and stems and moves to the actively growing areas of the plant, killing the entire plant. Sonar works by disrupting the formation of carotenoid pigments that are necessary for the plant to photosynthesize. The targeted plants die and decompose slowly. Usually, plants do not grow back for over a year, if the treatment is effective. Sonar at very low concentrations can be used to target Eurasian watermilfoil, but these concentrations must be closely monitored for the herbicide to work (Getsinger et al., 2002). Data collected and summarized by ReMetrix and BBMWD show a large reduction in plant biovolume and noxious aquatic plants (BBMWD and ReMetrix 2004) subsequent to Sonar application.

Vegetation stabilizes the sediment from resuspension and erosion by reducing wave activity. If all macrophytes within a lake are removed then higher turbidity in the water column might be observed due to more frequent occurrences of sediment resuspension. Sediment resuspension can have many negative effects on a lake's water quality, such as enhanced nutrient recycling, reduced water transparency, and excessive nuisance algal growth (Getsinger et al. 2002). Therefore, it is important that more of the beneficial species of aquatic plants in Big Bear Lake recolonize. Ideally, the lake would have a balanced composition of aquatic plant species, with no one aquatic plant forming a monoculture. In turn, this diversity of habitat would also support a diverse wildlife community.

Algae. Although algae is not one of the pollutants identified on the 1994 303(d) list as responsible for impairment in Big Bear Lake, nutrient enrichment often causes algal blooms. For this reason, data pertaining to algae are evaluated with respect to the nutrient listing for Big Bear Lake. Chlorophyll *a*[22] is an estimator of algae biomass.

According to many lake professionals, if the total P concentration in the water column is > 10 µg/L and/or the total nitrogen concentration in the water column is approximately 150 µg/L, blue-green algal blooms during the growing season can be expected (USEPA 2000b). Reviewing the phosphorus and nitrogen water column data for Big Bear Lake summarized in Table 2-7, Big Bear Lake would be expected to have such blue-green algal blooms. Big Bear Lake does experience algal blooms, but there are few written reports detailing their time and place. Researchers with the California Department of Fish and Game noted blue-green algae blooms during early May and summer to fall during their studies in the fall of 1976 through the fall of 1978 (Siegfried et al. 1978, 35; Siegfried and Herrgesell 1979b, 16-31). Also, on October 7, 1992, there was a newspaper article about a major algae bloom in Big Bear Lake (Atwood 1992). There have been some accounts of blooms in September 2000 as well (personal observation). For the most part, Big Bear Lake has experienced few problems with excessive algae. This could be because Big Bear Lake has an overabundance of macrophytes, and researchers have noted that either macrophytes or algae seem to dominate in a lake system, not both. If algae are abundant, the formation of algal mats can shade out light, inhibiting the growth of macrophytes; if macrophytes are abundant, algae appear not to grow (USEPA 2000b). In addition, the proliferation of coontail, a free-floating macrophyte that obtains nutrients from the water column, might also compete significantly with algae for nutrients in the water column. The other macrophytes observed in the lake are rooted and obtain their nutrients from the sediment. The limited algae problems in the lake could be due to the presence of a healthy zooplankton population that grazes on phytoplankton (Anderson et al. 2004). It should be noted that algal blooms have become more prolific and chlorophyll *a* values have increased from 2002 to 2003, probably as a result of the Sonar applications and removal of macrophytes, making more nutrients available for algae growth.

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[22] Total chlorophyll measures all the molecules of chlorophyll, including *a, b, c,* and *d.* Chlorophyll *a* is the primary pigment involved in photosynthesis and is most often the form of chlorophyll measured.

Table 2-7. Annual median concentrations of total N and total P in Big Bear Lake

Agency	Year	Total N Median (μg/L)	No. of samples	Total P Median (μg/L)	No. of samples
RWQCB	1992	1250	16	40	16
RWQCB	1993	955	2	25	2
RWQCB	1994	1450	4	40	4
BBMWD	1994	800	31	<50	14
BBMWD	1995	700	45	25	36
BBMWD	1996	800	37	<50	30
BBMWD	1997	700	15	<50	15
BBMWD	1998	600	8	95	8
BBMWD	1999	1000	11	25	11
BBMWD	2000	920	31	25	31
BBMWD/RWQCB[1]	2001	1196	40	57	40
BBMWD/RWQCB[1]	2002	1054	91	39	91
BBMWD/RWQCB[1]	2003	1352	119	64	119

[1]Medians calculated using both photic and bottom samples from Lake stations 1, 2, 6, and 9
½ the detection limit was used for non-detect values; <50 = all samples less than non-detect at 50 μg/L

Several researchers collected and analyzed algae samples in Big Bear Lake during the late 1960s (Pearson and Irwin 1972, 32-36); the 1970s (Irwin and Lemons 1974, 32-35; Siegfried et al. 1978, 30-35; Siegfried and Herrgesell 1979b, 16-25) and more recently, during 2002, as part of the TMDL Task Force monitoring (BBMWD 2002b) and 2003 (Anderson et al. 2004). The early researchers collected algae samples at multiple locations in Big Bear Lake during different seasons of the year. Overall, they found that diatoms were dominant during the early spring, green algae were dominant during the early summer, and blue-green algae were dominant during midsummer-fall. Phytoplankton analyses of samples collected on August 7, 2002, from the west end (MWDL1) and the east end (MWDL9) of Big Bear Lake showed that more than 50% of the total phytoplankton population was from the taxon Cyanophyta (blue-green algae), specifically *Anabaena circinalis* (58.8% of the total density for MWDL9) and *Microcystis aeruginosa* (55.5% of the total density for MWDL1). *Anabaena*, along with a few other genera of blue-green algae, dominate nitrogen fixation in lakes (Wetzel 2001, 207). There is a spatial gradient in phytoplankton densities, with the east end exhibiting much greater densities (more than three times) than that of the west end. This is likely the result of the generally westerly winds characteristic of the Big Bear Lake area, which transport algae from west to east. Anderson et al. (2004) also observed the most dominant algal group present in Big Bear Lake was that of cyanophytes (*Anabaena, Anacystis*, and *Microcystis*), followed by chlorophytes (*Eudorina, Pediastrum, Oocystis, Staurastrum* and *Scenedesmus*).

Chlorophyll *a* concentrations, which are used as an estimator of algae biomass, greatly increased during the late summer in all years (2001-2003). This appears to correlate with the senescence and decay of the macrophytes and the release of phosphorus, supporting phytoplankton growth. There is a trend of increasing chlorophyll *a* concentration from the western part of the lake to the east (Table 2-8).

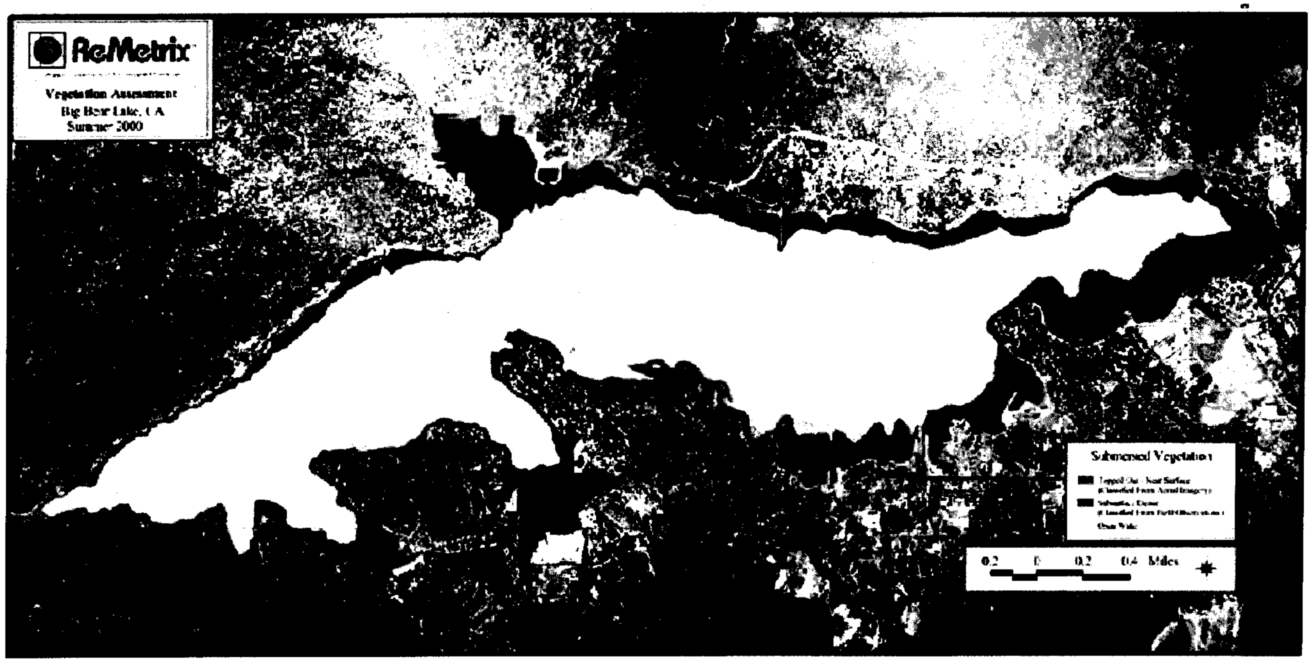

Figure 2-3. Map of near-surface and submerged dense vegetation, as analyzed using aerial photography collected in 2000.

Table 2-8: Chlorophyll *a* growing season averages (GS) and medians for 2001, 2002, and 2003 in mg/m^3 (equivalent to µg/L)

	TMDL Lake Station				
	MWDL1	**MWDL2**	**MWDL6**	**MWDL9**	**All stations**
GS Average 2001	10.3	10.5	16.8	31.9	17.4
GS Average 2002	13.6	12.0	18.6	33.5	19.4
GS Average 2003	12.2	15.0	19.7	33.1	20.0
Average for all 3 years	**12.2**	**12.9**	**18.7**	**33.0**	**19.2**
GS Median 2001	10.9	11.5	16.2	28.6	13.9
GS Median 2002	14.2	12.1	21.8	21.8	18.0
GS Median 2003	13.0	13.9	18.9	29.1	16.4
Median for all 3 years	**13.0**	**13.3**	**17.1**	**28.5**	**15.2**

Note: Growing season is defined as the period from May 1- Oct. 31

Dissolved Oxygen. Although Big Bear Lake is not on the 303(d) list as impaired due to low dissolved oxygen levels, nutrient enrichment often causes low dissolved oxygen concentrations. Anoxic conditions in the lake bottom allow the release of inorganic phosphorus and ammonia from the sediments, contributing to the internal loading of nutrients. For these reasons, data pertaining to dissolved oxygen are evaluated with respect to the nutrient listing.

As plants die, the dead plant matter (detritus) settles to the lake bottom and starts to decay. This process consumes oxygen and can result in anaerobic conditions in the lake bottom or hypolimnion. Plants respire both day and night. At night, respiration occurs but not photosynthesis. Respiration consumes oxygen and can result in oxygen depletion. With a prolonged decrease in oxygen at the lake bottom, the benthic community can change from aerobic organisms to anaerobic organisms. Oxygen depletion can also aid in the release of ammonia and phosphorus from sediments as the sediment -water interface becomes anoxic. As dead organic matter is broken down, un-ionized ammonia can also be produced. Depending on pH levels and temperature, this form of ammonia is toxic to fish. Massive beds of nuisance aquatic plants (e.g., Eurasian watermilfoil) can also outcompete more beneficial species of aquatic plants by reducing light penetration and shading out other vegetation types. These large mats of nuisance aquatic plants can also increase temperature and pH and decrease dissolved oxygen concentrations, which in turn affects the fishery.

Data collected as part of the TMDL Task Force Monitoring Program through the end of 2003 show that dissolved oxygen concentrations stratify during the middle of June and that the stratification continues throughout the end of July. Stratification is pronounced at the west end stations (MWDL1, MWDL2) and middle station (MWDL6). Although the lake does not experience long periods of thermal stratification, the stratification that occurs is enough to lower dissolved oxygen concentrations in the deepest parts of the lake during summer (Figure 2-4). The east end station (MWDL9) is generally well-mixed and experiences less pronounced dissolved oxygen stratification (Figure 2-5). The east end has an abundance of macrophytes and is shallower; both of these conditions are most likely the reasons that the east end does not experience more extreme, persistent low dissolved oxygen conditions. These measurements, however, were obtained from mid-morning to early afternoon when dissolved oxygen concentrations would be at their maximum. If vertical profiles were obtained in the early a.m., it is likely that the east end would experience very low dissolved oxygen concentrations due to the effects of respiration from the abundance of macrophytes. The results agree with those from previous researchers who have noted that dissolved oxygen stratification takes place primarily during the months of June, July, August and September (Pearson and Irwin, 1972, 7; Siegfried et al. 1978, 15-16). Dissolved oxygen levels fall below the Basin Plan Objective for Inland Waters (see Section 2.1) in all seasons, but primarily during the summer months (Table 2-9) and at depths greater than 11 meters (Table 2-10). Higher dissolved oxygen concentrations occur at the shallower east end of the lake during summer. Courtier and Smythe (1994) and Siegfried et al. (1978, 15) reported similar results.

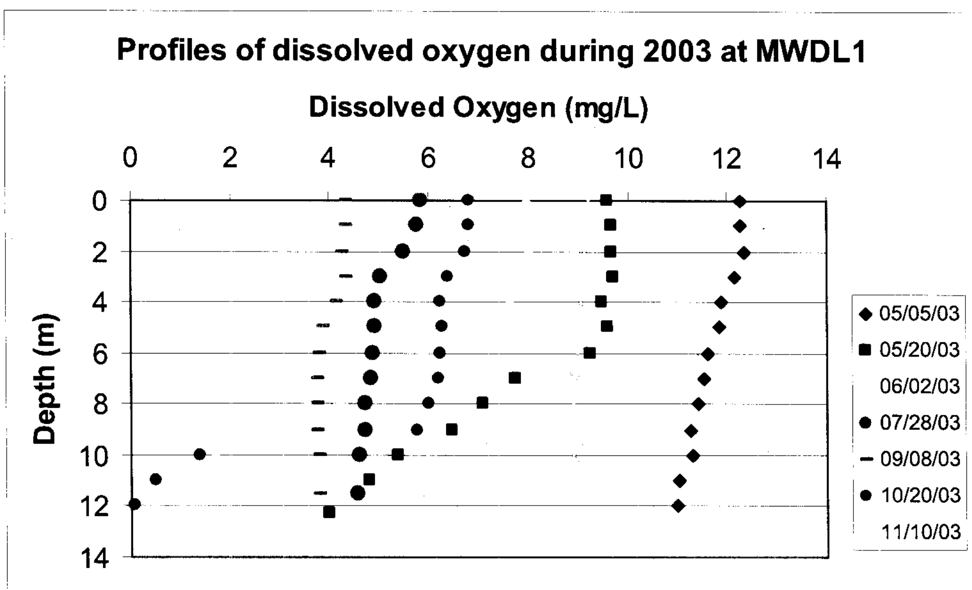

Figure 2-4: Dissolved oxygen profiles for MWDL1 (west end) during 2003

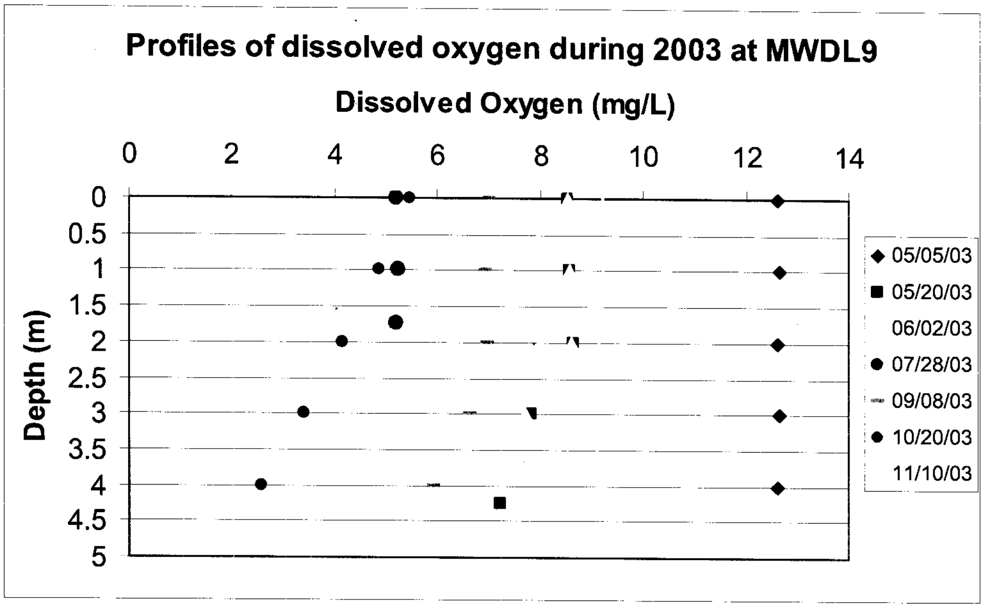

Figure 2-5: Dissolved oxygen profiles at MWDL9 (east end) during 2003

Table 2-9. Seasonal effects on compliance with the COLD dissolved oxygen objective – percentage of samples exceeding COLD dissolved oxygen objective

Season	Year 2001	Year 2002	Year 2003
Jan - March	NA	3%	0%
April - June	20%	5%	17%
July - Sept	32%	12%	43%
Oct - Dec	10%	0%	27%

NA = not applicable – sampling did not start until June 2001
Note: Results from all stations (1,2,6,9) combined

Table 2-10. Depth effects on compliance with the COLD dissolved oxygen objective

Depth	Percentage of samples exceeding COLD dissolved oxygen objective
0-5 meters	8%
6-11 meters	33%
>11 meters	78%

Note: Results from all stations (1,2,6,9) and all years (2001-2003) combined. East end station (MWDL9) is only represented by 0-5 meters.

3.0 Numeric Targets

Pursuant to federal TMDL requirements, quantifiable and measurable numeric targets that will ensure compliance with water quality standards (beneficial uses, water quality objectives and the state's antidegradation policy) must be established in each TMDL (USEPA 1999).

Big Bear Lake was placed on the Clean Water Act Section 303(d) list primarily due to impairment of the lake's warm and coldwater habitat (WARM and COLD) and wildlife habitat (WILD). However, the lake's water contact and non- contact water recreation (REC1 and REC2) beneficial uses are also impaired. As described in Section 2.0, the impairment results from the high levels of nutrient input and resultant overabundance of noxious aquatic macrophytes (e.g., Eurasian watermilfoil). The TMDLs and numeric targets for Big Bear Lake must be structured to guarantee protection of the COLD, WARM, WILD, REC1, and REC2 beneficial uses and attainment of the nutrient related water quality objectives specified in the Basin Plan (see Section 2.1). In addition, the TMDLs and numeric targets must ensure protection of Bear Creek, downstream of the lake.

3.1 Big Bear Lake Nutrient Numeric Targets

Both total phosphorus and total nitrogen are needed for the growth of macrophytes and algae in Big Bear Lake, and both must be controlled to ensure protection of the lake. Each of these constituents has been shown to be the limiting nutrient for algae growth in the lake under different conditions. Siegfried et al. (1978, 37) reported that phosphorus limited phytoplankton productivity in spring in Big Bear Lake, while nitrogen was the limiting nutrient from July through September. Siegfried and Herrgesell (1979b, 28) reported that phosphorus was the limiting nutrient in spring and also in July in the epilimnion[23]. Nitrogen was found to be the limiting nutrient in July in the hypolimnetic waters, corresponding with release of phosphorus from the sediments (28). Recent water column data (2001-2003) indicate that phosphorus is the limiting nutrient. Interim and final numeric targets for total phosphorus are proposed; a final target for total nitrogen is also recommended. These targets are shown in Table 3-1.

In addition, numeric targets are proposed for chlorophyll *a,* macrophyte coverage and the percentage of nuisance aquatic vascular[24] plant species in the lake. These response parameters are direct indicators of the status of impairment in the lake due to excessive plant growth (and the development of a monoculture by watermilfoil). Monitoring of these parameters will allow tracking of the recovery of the lake from its eutrophic status. These proposed targets are also shown in Table 3-1.

Based on the expected efficacy of programs currently being implemented by BBMWD to improve lake water quality, staff believes that the proposed interim targets can be achieved by 2010 (Table 3-1). Additional investigation of attainability and the water quality measures needed to achieve the proposed final numeric targets (particularly for total nitrogen – see discussion below), will be necessary. Accordingly, staff recommends that an extended schedule for compliance with the final targets be specified. As shown in Table 3-1, staff recommends that compliance with these targets be achieved as soon as possible but no later than 2015.

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[23] The epilimnion is the uppermost, warmest, well-mixed layer of a lake during summertime thermal stratification (Holdren, Jones and Taggart 2001, 374).

[24] Vascular plants are a group of plants, including macrophytes, that have specialized cells for conveying fluids within their tissues.

Table 3-1. Proposed numeric targets and indicators for the Big Bear Lake nutrient TMDL

Indicator	Target Value[c]	Reference
Total P concentration (interim)[a]	Annual average[d] no greater than 35 μg/L; to be attained no later than 2010	25th percentile of Big Bear Lake monitoring data from June 2001-April 2002
Total P concentration (final)[a]	Annual average[d] no greater than 20 μg/L; to be attained no later than 2015	Novotny and Olem 1994, 784; Carlson and Simpson 1996, as cited in USEPA, 2000b
Total N concentration (final)[a]	Annual average[d] no greater than 1000 μg/L; to be attained no later than 2015	25th percentile of Big Bear Lake monitoring data from June 2001-April 2002
Macrophyte Coverage[b]	30-60% on a total area basis by 2015[e]	Leidy 2003b
Percentage of Nuisance Aquatic Vascular Plant Species (final)[b]	95% eradication on a total area basis of Eurasian Watermilfoil and any other invasive aquatic plant species; to be attained no later than 2015[e]	Petr 2000, 23
Chlorophyll *a* concentration (interim)[b]	Growing season[f] average no greater than 10 μg/L; to be attained no later than 2010	25th percentile of Big Bear Lake monitoring data from June 2001-Oct 2001
Chlorophyll *a* concentration (final)[b]	Growing season[f] average no greater than 5.0 μg/L; to be attained no later than 2015	Carlson and Simpson 1996, as cited in USEPA 2000b

[a] source targets related to load allocations/waste load allocations (see Section 5.0)
[b] monitoring targets that will not be used for load allocations/waste load allocations
[c] compliance with the targets to be achieved as soon as possible, but no later than the date specified
[d] Annual average determined by the following methodology: the nutrient data from both the photic composite and discrete bottom samples are averaged by station number and time; a calendar year average is obtained for each sampling location; and finally, the separate annual averages for each location are averaged to determine the lake-wide average. The open-water sampling locations used to determine the annual average are MWDL1, MWDL2, MWDL6, and MWDL9.
[e] To be calculated as a 5-yr running average based on measurements taken at peak macrophyte growth as determined in the Aquatic Management Plan (see Attachment A –Task 8).
[f] Defined as the period from May 1-October 31

No wasteload or load allocations would be derived from the targets for the response indicators (chlorophyll *a*, macrophyte coverage and percentage of nuisance aquatic vascular plant species). This is because the correlation between nutrient loads and macrophyte coverage or biomass are obscure and chlorophyll *a* concentrations cannot be predicted from total phosphorus. For example, a log-log plot of chlorophyll *a* and total phosphorus showed little correlation ($R^2 = 0.37$) (Figure 3-1). Complex nutrient dynamics, including the fact that rooted aquatic vascular plants obtain nutrients from both the sediment and the water column, complicate the evaluation of any such correlations. However, further research in this area might provide some means of predicting macrophyte biomass or coverage from nutrient loads (USEPA 2000b).

Board staff recognizes that much more information on the nature and extent of beneficial use impairment by macrophytes is needed to refine the targets. For example, the effects of increased/decreased macrophyte coverage and a more diverse macrophyte habitat on the growth of macroinvertebrates, zooplankton, phytoplankton, as well as fisheries habitat, need to be explored. The proposed targets are based on protecting the aquatic life and recreational beneficial uses of the lake. If the total phosphorus and nitrogen targets are met while the other targets are not, or vice versa, the numeric targets will be re-evaluated and revised accordingly. A phased TMDL approach is recommended to conduct further appropriate investigations and to review and revise the TMDLs as necessary.

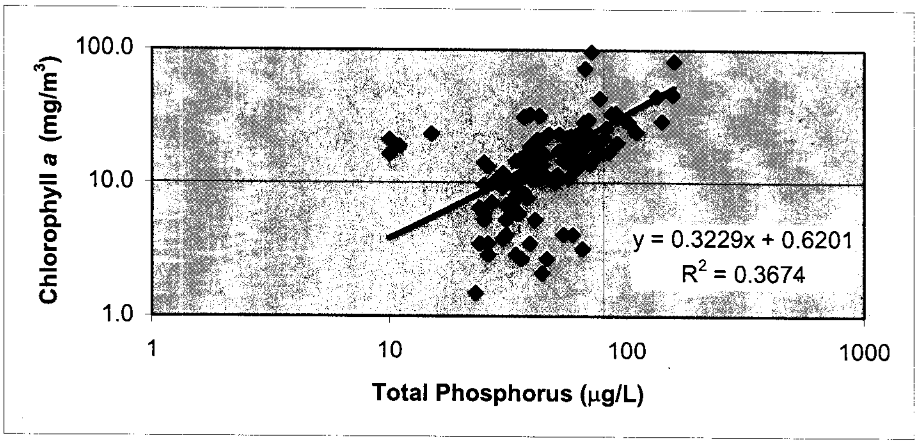

Figure 3-1: Chlorophyll *a* as a function of total phosphorus (Data from 2001-2003)

To establish the numeric targets, Regional Board staff first considered the use of established numeric nutrient objectives. As discussed in Section 2.1, the Basin Plan specifies numeric water quality objectives for both phosphorus and nitrogen for Big Bear Lake. The total phosphorus objective of 150 μg/L and the total inorganic nitrogen (TIN) objective of 150 μg/L were established in the 1975 Basin Plan based on the data then available. However, according to the National Eutrophication Survey (Novotny and Olem 1994, 784), total phosphorus values of <10 μg/L are indicative of oligotrophic conditions; mesotrophic conditions are observed at 10-20 μg/L of total phosphorus; and eutrophic conditions are observed with total phosphorus concentrations >20 μg/L. Clearly, based on these values, the present numerical water quality objective of 150 μg/L of total phosphorus allows for hypereutrophic conditions. Similarly, it appears likely that the established total inorganic nitrogen objective is not protective of beneficial uses. Although inorganic nitrogen is the bioavailable form of nitrogen, organic forms of nitrogen can be transformed into a bioavailable form (note: organic nitrogen comprises over 90% of the total nitrogen in Big Bear Lake for data collected in 2001-2003). Therefore, it is essential to control the total amount of nitrogen, not just the inorganic forms. It appears that revised nitrogen and phosphorus objectives need to be developed and considered[25]. If and when such objectives are incorporated in the Basin Plan, it would be appropriate to apply them in the

[25] It may be appropriate to consider numeric or narrative objectives specific to Big Bear Lake for chlorophyll *a*, macrophyte coverage and/or species diversity, rather than or in addition to numeric objectives for phosphorus and nitrogen, given (1) the significant uncertainties that exist regarding the dynamics of these nutrients in the lake; (2) concerns regarding the attainability of target phosphorus and nitrogen concentrations (see further discussion in this section); and, perhaps most importantly, (3) the direct nature of the evidence of impairment that is provided by these parameters. The proposed implementation plan (Task 10) reflects this consideration.

selection of revised numeric targets and refinement of the TMDLs. Development of these objectives is identified as a part of the Implementation Plan for these TMDLs (see Section 9.1, Implementation Recommendations).

Until appropriate revised objectives are established, alternative methods of identifying numeric targets must be used. Regional Board staff evaluated other alternatives to select both water quality indicators and target values. USEPA recommends the following approaches for states in developing nutrient criteria, listed in order of preference: 1) Develop nutrient criteria based on localized conditions and protection of designated beneficial uses using the process described in EPA's Technical Guidance Manuals for nutrient criteria development; 2) Adopt EPA's section 304(a) water quality criteria (i.e., EPA's recommended nutrient Ecoregion values); 3) Use other scientifically defensible methods to develop nutrient criteria protective of designated uses (USEPA 2000a). USEPA recognized that developing nutrient criteria on a lake-by-lake or stream-by-stream basis would be expensive and time consuming. Therefore, USEPA developed recommended reference values for different types of bodies of water for each ecoregion. USEPA stressed the need to use both causal (total phosphorus and total nitrogen) and response (e.g., algal chlorophyll and some form of water clarity, i.e., turbidity or Secchi depth) indicators for lakes/reservoirs and rivers/streams. States can then either adopt the Section 304(a) water quality criteria for nutrients or use the recommended ecoregion values as guidance in developing their own nutrient criteria.

The proposed numeric targets for the Big Bear Lake TMDL were developed based on USEPA's recommended options 1 and 3. Because Big Bear Lake is not in a pristine condition and most likely will always remain in a mesotrophic to eutrophic status (Leidy 2003a) (Section 2.0), the recommended Nutrient Ecoregion II[26] values (shown in Table 3-2) were not used for either the proposed interim or final numeric targets, as these values apply to lakes that are minimally impacted by human activity. The interim numeric targets for the Big Bear Lake nutrient TMDLs were developed based on USEPA's Nutrient Criteria Technical Guidance Manual for lakes and reservoirs (USEPA 2000b). In developing nutrient criteria, data are collected from so-called reference conditions and some percentile (e.g., lower or upper 25th percentile of the dataset) is chosen to be the criterion. However, when, as is the case for Big Bear Lake, there are no ideal reference conditions, then the conditions observed presently serve as the reference conditions and the criterion chosen should be based on a lower percentile (i.e., the 25th percentile) of data (USEPA 2000b). As discussed in more detail below, the 25th percentile of data collected from 2001-2002 was used to calculate the recommended interim numeric total phosphorus and chlorophyll a targets and final total nitrogen numeric target. The proposed final total phosphorus and chlorophyll *a* numeric targets for the Big Bear Lake nutrient TMDLs were developed using the third approach recommended by USEPA. Specifically, a trophic index system (see Appendix C) was used to derive the final numeric targets needed to move Big Bear Lake from eutrophic to mesotrophic status.

[26] Nutrient Ecoregion II includes the mountainous areas of 11 states (Washington, Oregon, California, Idaho, Montana, Wyoming, New Mexico, Colorado, Utah, Arizona, South Dakota). Data sets from Legacy STORET, and EPA Region 10 were used to assess nutrient conditions from 1990 to 1999, with most of the data obtained from Oregon, Washington, Colorado, and Utah. No data were obtained for the Southern California Mountains subecoregion within Ecoregion II for lakes (USEPA 2000a).

Table 3-2. EPA's recommended nutrient criteria for Ecoregion II in μg/L

Indicator	Recommended Value for Lakes Ecoregion II
Total Phosphorus	8.8
Total Nitrogen	100
Chlorophyll *a*	1.9
Secchi (meters)	4.5

Source: USEPA 2000a

Derivation of the proposed targets for Big Bear Lake is discussed in more detail below.

3.1.1 Phosphorus and Nitrogen

Numeric Targets

The proposed interim target for total phosphorus is 35 μg/L[27] as the annual average concentration of both the photic composite and bottom discrete samples at the four main TMDL lake monitoring stations (MWDL1, MWDL2, MWDL6, and MWDL9). This number represents the 25th percentile of the total phosphorus concentrations during the monitoring period from June 2001- April 2002 (see Appendix B-Minitab results). This time period is identified as a reference state since the application of an aquatic herbicide, Sonar, took place after this time (in May 2002). There is no proposed interim nitrogen target (see Section 5.1 for further discussion of nitrogen numeric targets); an annual average of 1000 μg/L[28] is the proposed final nitrogen numeric target (see Appendix B-Minitab results).

The proposed final target for total phosphorus is 20 μg/L as the annual average concentration of both the photic composite and bottom discrete samples at the four main TMDL lake monitoring stations (MWDL1, MWDL2, MWDL6, and MWDL9). This value is the concentration that the USEPA considers as the dividing point between mesotrophic and eutrophic conditions (Novotny and Olem 1994, 784). A value of 20 μg/L will produce a Trophic Status Index (TSI) of 47 (see Appendix C), which is on the high end of the mesotrophic level (Carlson and Simpson 1996, as cited in USEPA 2000b). If a TN/TP ratio of 10:1 (assuming phosphorus limitation) and the value of 20 μg/L for total P were used, then the corresponding total N target value would be 200 μg/L. However, it appears that this value is too stringent for Big Bear Lake and could not be met. WASP model results (discussed in Section 5.1) support this contention. Therefore, the proposed final target for total nitrogen is 1000 μg/L as the annual average concentration of both the photic composite and bottom discrete samples at the four main TMDL lake monitoring stations (MWDL1, MWDL2, MWDL6, and MWDL9). Even if the total nitrogen target is set at this level, no WASP model simulations of nutrient control measures

[27] The 25th percentile calculates to 31 μg/L. Given uncertainties in the data, this value was simply rounded up to 35 μg/L for the purposes of these TMDLs.
[28] The 25th percentile calculates to 990 μg/L. Given uncertainties in the data, this value was simply rounded up to 1000 μg/L for the purposes of these TMDLs.

results in compliance. As discussed in Section 5.1, staff believes that this is at least partially due to the limitations of the WASP model. However, further investigations of the propriety and attainability of this recommended target are clearly necessary. Again, this supports the recommendations for a phased TMDL approach and extended schedule for compliance with the final numeric targets.

3.1.2 Macrophyte Coverage

According to the most recent data, collected by ReMetrix, Inc. in July 2000, there were approximately 781 surface acres of submersed vegetation in Big Bear Lake (ReMetrix 2001, 4). At that time, the lake had an elevation of approximately 6738 feet (obtained from the BBMWD's website), corresponding to a water surface area of 2,569 acres (Tetra Tech 2004b). Based on these data, approximately 29% of the surface area of the lake was covered with submersed aquatic vegetation. BBMWD reported (2002a) that the predominant species is Eurasion milfoil (~ 73%), followed by coontail (~20%) and other species (~7%). BBMWD is able to control approximately 240 acres (31%) of the aquatic plant growth by harvesting. About 86% of the aquatic plant harvesting occurs around private docks, and the other 14% occurs where navigational hazards need to be removed or where public access needs to be improved. Harvesting of the Eurasian watermilfoil is not a preferred control because it can spread Eurasian watermilfoil fragments to other areas of the lake and can impact the bottom biota (Madsen 2000).

Numeric Target

The proposed numeric target is specified as a range of 30-60 percent macrophyte coverage on a total lake basis. Recent findings (Leidy 2003b) suggest that approximately 60 percent of the reservoir bottom can support coverage of rooted aquatic macrophytes in Big Bear Lake. Provided that the macrophyte community is diverse, there is no reason to reduce this level of coverage. However, macrophyte reductions may be necessary to prevent dominance of nuisance/noxious species. Reducing macrophyte coverage below 60% will always require maintenance. Leidy (2003b) does not recommend reducing the macrophyte coverage to less than 30 percent in order to maintain a balanced composition of aquatic fauna within the lake. Furthermore, Leidy (2003b) states that an even distribution of aquatic plants within the perimeter of the lake is also desirable. Studies conducted on the optimal percentage of macrophyte coverage from a fisheries perspective have shown that aquatic plant coverage can range from 20-36% on a total area basis and that in eutrophic lakes, aquatic plant coverage in the littoral zone should range from 20-40% (Schneider 2000). It is known that aquatic macrophytes are necessary if a healthy fishery is to be maintained. When future studies are conducted to establish the link between macrophyte coverage and a healthy fishery in Big Bear Lake, the proposed numeric target for macrophyte coverage will be reviewed and revised accordingly.

3.1.3 Percentage of Nuisance Species

Eurasian watermilfoil and coontail proliferate in Big Bear Lake due to the excessive levels of nutrients in the lake (see Section 2.2). Reduction and/or the eradication of Eurasian watermilfoil will allow a more diverse plant community to flourish, which in turn will improve fisheries and other wildlife habitat. Petr (2000, 23) states that native plants provide better habitat for aquatic invertebrates than does Eurasian watermilfoil.

Reducing nutrient loading should result in the control of Eurasian watermilfoil, coontail and other invasive aquatic vascular plant species. However, this will need to be supplemented with spot treatments of herbicide, hand pulling of weeds, and other methods of eradication that might be identified. In addition, it will be necessary to educate the public regarding the ways that they can prevent the appearance/reappearance of invasive aquatic plants in the lake. Vessel wash off areas will need to be provided to prevent the introduction of any invasive aquatic plant elsewhere, as well as the reintroduction of these species to the lake.

Reductions in nutrient loading would likely also affect the growth of beneficial species of macrophytes, which are necessary to support the wildlife-related beneficial uses of the lake. A careful balance will need to be struck between nutrient reductions and the need to support some types of macrophyte growth. As suggested above (Section 3.1), it may be that adjustments will need to be made to the numeric targets (and objectives) for phosphorus and nitrogen, the causal indicators, based on demonstrated needs to meet the response indicator targets, which are more indicative of the actual health of the lake and its beneficial uses. This will require integration of nutrient loading considerations with aquatic plant management plans, including dredging activities.

Numeric Targets

The proposed final target, to be achieved as soon as possible but no later than 2015, is a 95% eradication of Eurasian watermilfoil and any other invasive aquatic vascular plant species on a total area basis.

3.1.4 Chlorophyll *a*

Chlorophyll *a* is used as an estimator of algae biomass. Values greater than 10 µg/L are considered to be indicative of eutrophic conditions, while values less than 4 µg/L are representative of oligotrophic status (Novotny and Olem 1994, 784).

Numeric Target

The proposed interim target for chlorophyll *a* is a growing season average of 10 µg/L, based on the photic composite samples at the four main TMDL monitoring stations (MWDL1, MWDL2, MWDL6, and MWDL9) in the water column. This number represents the 25th percentile of the chlorophyll *a* concentration measured during the monitoring period from June 2001- October 2001 (i.e., the growing season). This time period is identified as a reference state since the application of an aquatic heribicide, Sonar, did not take place until May 2002. The target is recommended as a growing season average (May 1 through October 31) since the critical condition for lake water quality effects from algae growth occurs during this time frame.

The proposed final target for chlorophyll *a* is 5.0 µg/L, which corresponds to a TSI of 47 (see Appendix C). This is on the high end of the mesotrophic level (Carlson and Simpson 1996, as cited in USEPA 2000b).

4.0 Source Assessment

Current sources of nutrient loading to Big Bear Lake and its tributaries were evaluated using computer modeling and direct load measurements. The source assessment discussion below describes the sources of nutrients and summarizes the nutrient load estimates. Values from the literature were used in the current Hydrological Simulation Program Fortran (HSPF) model to estimate nutrient loads from the general land use categories. For more detailed information on the watershed modeling and external nutrient source assessment please refer to the nutrient budget report (BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003) and to the updated model runs (Hydmet, Inc. 2004). Note that all of the following graphs and tables for the flow and HSPF loads were created by Regional Board staff using data supplied by Hydmet, Inc (2004).

External nonpoint sources are grouped into general land use categories (forest and resort). Point sources include urban runoff from high density urban and residential land use. The urban runoff category represents land uses that are within the City of Big Bear Lake, the County of San Bernardino and Caltrans. The urban discharges from these areas are regulated under NPDES permits issued to the San Bernardino County Flood Control District, the County of San Bernardino and the City of Big Bear Lake, NPDES No. CAS 618036 (Regional Board Order No. R8-2002-0012) and Caltrans, Order No. 99-06-DWQ.

The major categories of sources that were evaluated in the Big Bear Lake watershed were:

- runoff from forest and resort land uses
- runoff from residential and high density urban land uses (combined into the generic term urban runoff)
- atmospheric deposition
- internal nutrient loads from lake bottom sediments
- internal nutrient loads from macrophyte senescence and die-off

Other sources of nitrogen and phosphorus within the Big Bear Lake watershed that were not assessed separately, but instead were lumped into the generic "urban runoff" and that would be expected to contribute nutrient loads include golf courses, parks, runoff from residential and commercial irrigation and fertilization practices, runoff from the trout pond and the zoo, runoff associated with livestock, and septic systems. As part of the phased TMDL approach, these sources should be evaluated and monitored to obtain source-specific nutrient concentrations within this watershed. These values would then be used to rerun the current HSPF model to reassess the proposed numeric targets and wasteload and load allocations.

The HSPF model simulated streamflow, total suspended sediment and nutrients and output was provided by water years. The hydrologic component of the model was calibrated to the limited available data on monthly Big Bear Lake inflow[29] by three independent procedures. These procedures included preparation of a lake water balance, conduct of a Plunge Creek regression and conduct of a Santa Ana River regression. Note that Plunge Creek, although in an adjacent watershed, has similar hydrology to the Big Bear Lake watershed, and the Santa Ana River gaging station located downstream of Big Bear Lake was used to calibrate the outflow at Big Bear Lake. These procedures had to be used to simulate flows since there are currently no gaging stations in the Big Bear Lake

[29] Weirs and flow meters installed in 2002 at key locations within the watershed were used to sample stormwater and record flows. However, much more flow and load data need to be collected before there will be a better understanding of the duration, magnitude and type of flow (e.g., baseflow, storm events or snowmelt) that delivers nutrients to the lake.

watershed and, again, there are few flow data available for the watershed. One of the limitations in using the HSPF model is that the events that were sampled for calibration purposes were of low intensity and consisted of rainfall/snowmelt in dry years. These results could not be extrapolated to average precipitation or wet years. Fits between the simulated and observed flows for calibration purposes were within 10% for annual runoff and 20% for monthly runoff. This was considered sufficient due to the fact that there were few local tributary inflow data, and the only recorded precipitation data records were near the lakeshore, with no records of higher elevation precipitation or snow cover (BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003). As part of the phased TMDL approach, additional flow data collected during higher intensity rainfall and snowmelt and data collected from a high elevation weather station (proposed for installation) will be used to calibrate the HSPF watershed model.

The water quality component of the HSPF model simulated total nitrogen, total phosphorus, total kjeldahl nitrogen (TKN), nitrate, nitrite, orthophosphate and ammonia, while the sediment component of the model simulated total suspended sediment. HSPF model calibrations for external nutrient loads based on Big Bear Lake watershed data were not performed since the existing observed data were not adequate for this purpose (BBMWD, Hydmet, Inc., and AquAeTer, Inc., 2003).

Fourteen water years, 1990-2003, were simulated using the HSPF model, though only five of those years, 1999-2003, were used to calculate the TMDLs due to the more limited simulation period of the lake model (i.e., the WASP model)[30]. As discussed in Section 5.0, the WASP lake model was used to determine nutrient load capacity and to evaluate reductions required from external and internal sources. Although some lake water quality data were collected during average and wet years (see Section 2.2), these data, for the most part, were not adequate for the WASP modeling effort because: 1) total phosphorus detection limits were too high and therefore, the majority of samples for total phosphorus were non-detect; 2) inorganic phosphorus and nitrogen detection limits were too high and therefore, the majority of samples for inorganic phosphorus and nitrogen were non-detect; 3) ammonium nitrogen was rarely measured, therefore, inorganic nitrogen determinations were based only on nitrate and nitrite; 4) the WASP model needs inputs of both inorganic and organic phosphorus and nitrogen and the data collected prior to 2001 were not adequate. ***The proposed TMDLs are based on the average of all loads from the period of record of 1999 to 2003. This period only includes loads from dry hydrological conditions.*** This report also presents the average external loads for 1990-2003, a period that incorporates loads from wet, dry, and average hydrological periods, and the loads from 1993, a wet hydrological period. The latter results are presented for comparison purposes only; because of the inability to calibrate the WASP lake model for wet and average hydrologic conditions, these loads were not considered in the development of the recommended TMDLs. The proposed implementation plan includes tasks designed to address this deficiency.

The Watershed Database Management (WDM) file consists of all the meteorological time series data used for the hydrology simulation of the HSPF model and was assembled for the time period of October 1948 to December 2002 (54 years). The WDM file was extended through December 2003 for the WASP modeling effort conducted by Tetra Tech in 2004. Because hourly precipitation data were not available or published for any location in the San Bernardino Mountains before October 1948,

[30] The WASP model required the HSPF output in a different format than that which was delivered to the RWQCB. Staff needed HSPF output corresponding to individual tributaries while WASP required output corresponding to the 10 lake segments used in the WASP model setup (see Section 5). The two model simulations used the same data and .wdm file, but the output of the two runs was provided in two different formats. The WASP model input loads were based on calendar years, while the HSPF output provided to staff was based on water years. Staff used the last three months of 2003 (October, November, and December) from the HSPF output provided for the WASP model to determine loads and flow from the 2003 calendar year.

model simulations prior to 1948 were not possible (BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003).

The GIS data used to characterize the Big Bear Lake watershed consisted of subbasins, mean annual precipitation, elevation/aspect, land use, and soils. The datasets contained the following attributes: 1) four land uses (forest, resort, residential, and high density urban); 2) two elevation zones (>7,500 ft and <7,500 ft); 3) two aspects (land oriented facing north or facing south); 4) four precipitation zones (15-20", 20-25", 25-30", and 30-35"); and, 5) two dominant soil types (low and high water holding capacity). By combining the GIS datasets, a total of 128 types of pervious surfaces (PERLND in the HSPF model) were obtained. Ultimately, only 30 pervious land use types were used to define all the possible combinations of the variables. The other combination types simply were not present or had areas that were less than 10 acres. Eight impervious land use types were used in the Big Bear Lake watershed model (BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003).

The surface area of the lake was estimated at approximately 2,282 acres. Based on the bathymetry provided by ReMetrix in 2001, the surface area of the lake at full pool (i.e., at a lake elevation of 6,743.2 ft.) was determined to be 2,808 acres, with a corresponding volume of 72,696 af (compare to Table 1-1) (BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003). Due to sedimentation, the lake has lost some storage capacity since the original gage height-lake capacity chart was created in 1977. The values cited above, based on the newest bathymetry obtained in 2000, were used in the HSPF model.

Hydrology of the Big Bear Lake Watershed

The summary of HSPF simulated inflows for the period of record 1990 to 2003 around the average total flow shows that 1993 was the wettest year during this period (Figure 4-1). In fact, out of the entire 14-year period, there were only 3 years with flow above the average total flow of 14,032 AF (1993, 1995 and 1998). The majority of the years are below the average total flow. Low-flow conditions typically occur from July through October, with the minimum monthly average simulated flow of 34.7 AF recorded during August (Figure 4-2).

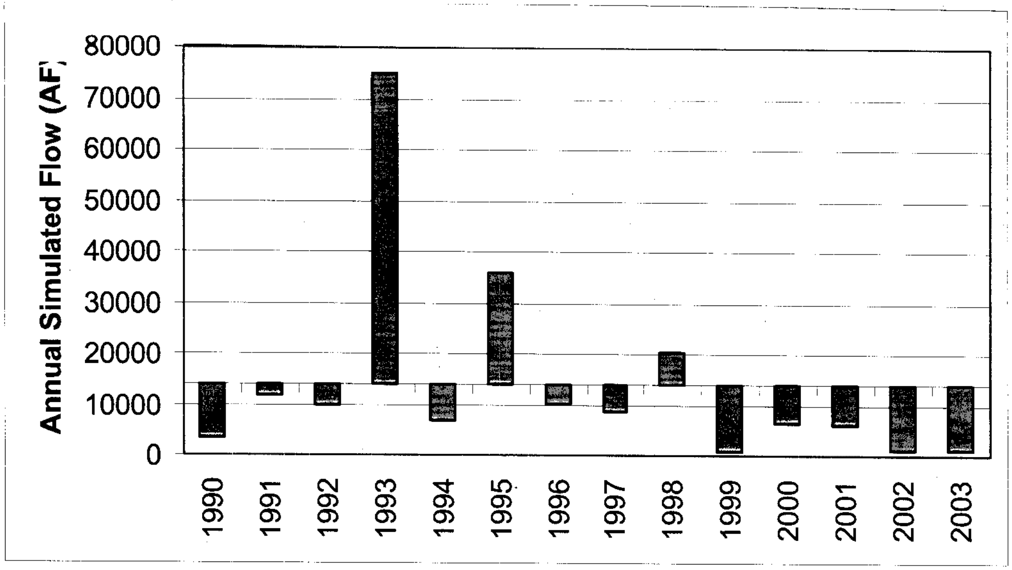

Figure 4-1: Variation of annual total flow from HSPF model land uses around average total flow for the period of record 1990-2003 (CY)

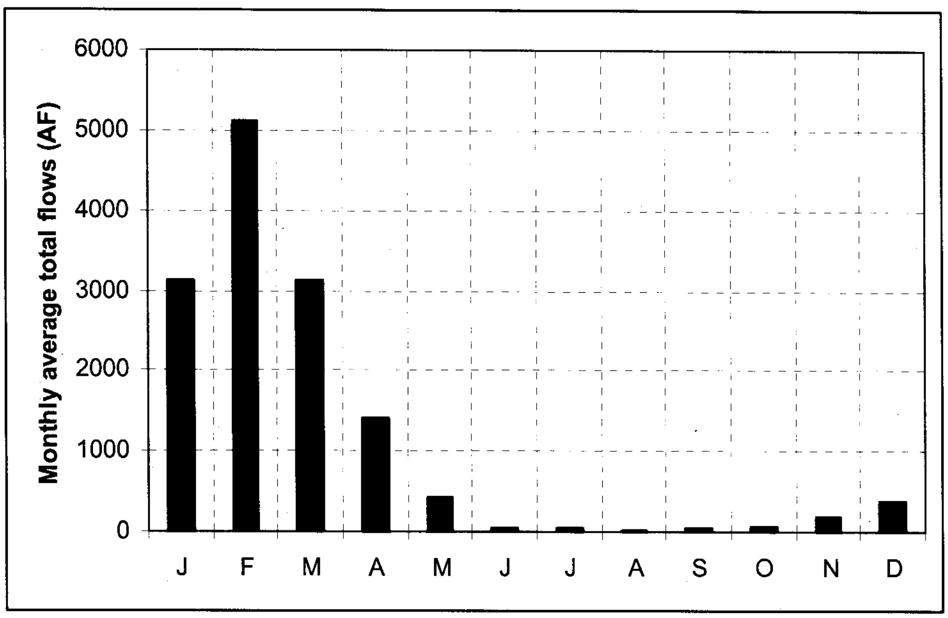

Figure 4-2: Monthly trends of average total flow for Big Bear Lake, 1990-2003 (CY)

4.1 Loads from Forest, Resort and Urban land uses

Nutrient loads in runoff from forest, resort and urban land uses include phosphorus and nitrogen. These water quality constituents were simulated by the PQUAL module section in HSPF using simple relationships with sediment and water yield. Figures 4-3 and 4-4 show nutrient loads from forest, resort and urban land uses during two different periods. The highest total nitrogen loads come from urban land uses (Figure 4-3) while the highest total phosphorus loads come from the forested areas during the period 1990-2003 and from urban land uses during the period 1999-2003 (Figure 4-4). Over 80% of the total nitrogen in Big Bear Lake is associated with the dissolved form. Conversely, most of the phosphorus is associated with the particulate phase (i.e., granitic sand, of which a fraction is the mineral apatite[31]), with the greatest loads from the forested areas during wet hydrological periods.

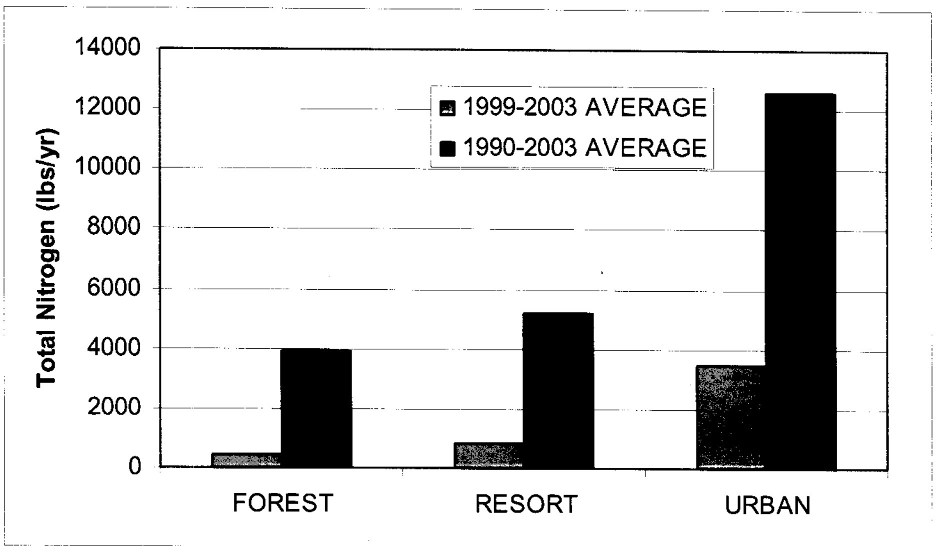

Figure 4-3: Average annual nitrogen loads from land uses for 5 years, 1999-2003, and 14 years, 1990-2003 (CY)

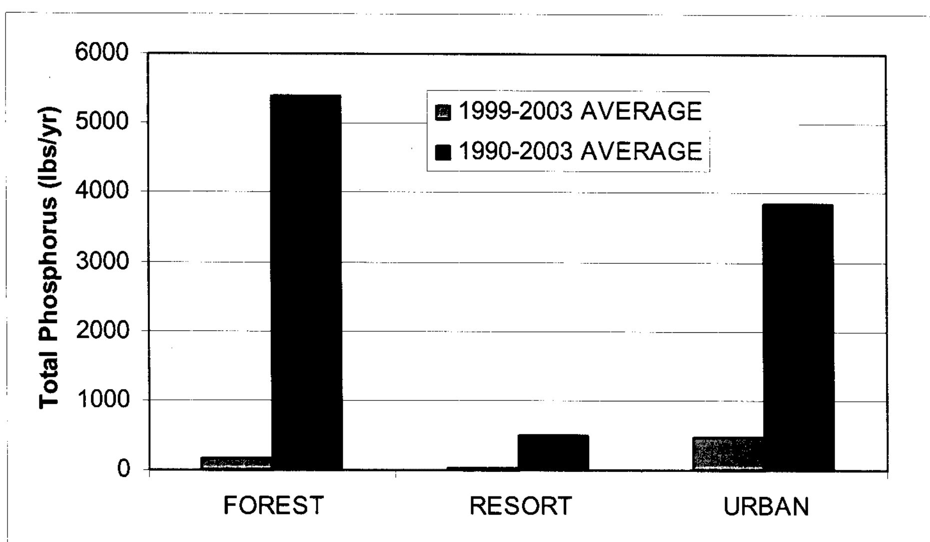

Figure 4-4: Average annual phosphorus loads from land uses for 5 years, 1999-2003, and for 14 years, 1990-2003 (CY)

[31] Apatite is a class of minerals that are insoluble calcium phosphates ($Ca_3(PO4)_2$).

Annual total nitrogen and total phosphorus loads to Big Bear Lake simulated by the HSPF model for 1990 to 2003 are shown in Table 4-1. The largest total nitrogen and phosphorus loads, 130,747 lbs/year and 98,010 lbs/year, respectively, during the last 14 years (1990-2003) were observed in 1993, which corresponded to the wettest year and the greatest external inflows. Total nitrogen and total phosphorus loads for the last 5 years (1999-2003) averaged 4,716 lbs/yr and 683 lbs/yr, respectively (Table 4-1). The annual average loads during the 14-year period, 1990-2003, are more than 4 times the annual average loads for the period of record from 1999-2003. These differences in the annual average loads for these two time spans are attributed to wet hydrological periods that occurred in 1993, 1995, and 1998. It is worth noting that in the case of phosphorus, although wetter years would bring more phosphorus into the system, all of this additional phosphorus might not be readily bioavailable (see discussion in Section 4.3).

Table 4-1. Simulated annual nutrient loads to Big Bear Lake (calendar years)

CALENDAR YEAR	PRECIPITATION AT BIG BEAR LAKE DAM (IN)+	TOTAL ANNNUAL INFLOW (AF)	TOTAL PHOSPHORUS (LBS)	TOTAL NITROGEN (LBS)
1990	22	3271	486	5001
1991	38	11665	1813	18466
1992	44	9677	990	12843
1993	74	74610	98010	130747
1994	32	6852	811	9969
1995	49	35880	19602	49693
1996	41	10262	2357	10925
1997	27	8742	1207	11413
1998	50	20246	7676	30986
1999	13	852	269	2120
2000	25	6254	1910	8365
2001	31	5906	667	8588
2002	15	1104	263	2077
2003	32	1130	308	2429
1999-2003 AVERAGE	**23**	**3049**	**683**	**4716**
1990-2003 AVERAGE	**35**	**14032**	**9741**	**21687**
MAX	74	74610	98010	130747
MIN	13	852	263	2077

+Annual rainfall data are from January 1 through December 31 (*Data Source:* BBMWD 2004b)

Based on the HSPF simulations, on an annual basis for 1999-2003, runoff from forest areas contributed 10% of the total nitrogen load and 26% of the total phosphorus load; runoff from resort areas contributed 17% of the total nitrogen load and 5% of the total phosphorus load; runoff from urban areas contributed 73% of the total nitrogen load and 70% of the total phosphorus load. These loadings are tabulated and summarized in Table 4-2.

Nitrogen from the urban land uses is likely a result of a combination of dryfall[32] and wet atmospheric deposition. Other nitrogen sources from residential and high density urban areas would likely include fertilizers. Dry atmospheric deposits, street deposition, and organic litter would be expected to build up on the impervious land surfaces. Rainfall would wash these sources off into the receiving bodies of water due to the reduced ability of water to infiltrate into the ground. The volume of runoff from the various land surfaces drives the nutrient loads from impervious land surfaces. In HSPF, nutrient loads from pervious land segments move along three paths: overland flow, interflow (i.e., subsurface runoff) and groundwater flow. Most of the phosphorus is associated with the sediment/particulate discharge present when surface runoff occurs, with the most significant contributions from forest land use.

[32] Dryfall is atmospheric deposition of nutrients without accompanying precipitation.

Table 4-2. Total annual simulated nutrient loads from HSPF model land uses for the 14 year period, 1990-2003 (CY)

	TP LOADS FROM LAND USES (LBS/YEAR)				TN LOADS FROM LAND USES (LBS/YEAR)			
WATER YEAR*	FOREST	RESORT	URBAN	TOTAL	FOREST	RESORT	URBAN	TOTAL
1990	53	16	416	486	382	876	3743	5001
1991	371	77	1365	1813	2203	4840	11423	18466
1992	226	51	714	990	1717	3374	7752	12843
1993	60325	5057	32628	98010	25478	31504	73764	130747
1994	153	37	621	811	1143	2396	6431	9969
1995	8992	949	9661	19602	11630	11989	26074	49693
1996	1202	189	967	2357	2586	2505	5835	10925
1997	348	67	792	1207	2409	2823	6181	11413
1998	2908	433	4334	7676	4904	8494	17588	30986
1999	3	4	261	269	9	64	2047	2120
2000	741	119	1049	1910	1333	1709	5323	8365
2001	126	33	508	667	936	2157	5495	8588
2002	3	4	256	263	10	64	2003	2077
2003	3	4	301	308	11	62	2356	2429
1999-2003 AVERAGE	**175**	**33**	**475**	**683**	**460**	**811**	**3445**	**4716**
% OF TOTAL AVERAGE	26%	5%	70%		10%	17%	73%	
1990-2003 AVERAGE	5390	503	3848	9741	3911	5204	12572	21687
% OF TOTAL AVERAGE	55%	5%	40%		18%	24%	58%	
MAX	60325	5057	32628	98010	25478	31504	73764	130747
MIN	3	4	256	263	9	62	2003	2077

Note: The 1999-2003 average is included because of the limitations of the WASP model that restricted the modeling to this period (see Section 5.1).

4.2 Atmospheric Deposition

Nutrient inputs from rainfall as well as dryfall may be significant sources of nutrient loads to lakes. Sources of nitrogen air emissions are agriculture (i.e., CAFOs[33]), transportation, and industry. The forest surrounding Big Bear Lake is likely an additional source. Studies indicate that nitrogen saturation in the forested areas in the San Bernardino mountains has likely occurred (Bytnerowicz and Fenn 1996). While undisturbed forests are typically nitrogen poor and tend to assimilate all of the atmospherically deposited nitrogen, forests that are exposed to excessive amounts of atmospheric nitrogen become nitrogen saturated (Bytnerowicz and Fenn 1996). Nitrogen saturation can result in high concentrations of nitrate in local streams that drain nitrogen saturated forests (Fenn and Poth 1999).

No direct precipitation or dryfall samples were collected for Big Bear Lake in recent years, although precipitation samples were collected during the 1970s (Irwin and Lemons 1974, 5-6). Irwin and Lemons (1974, 26-27) estimated that 31,765 lbs of nitrogen and 3,177 lbs of phosphorus entered Big Bear Lake by precipitation in the 1970s. The effects of atmospheric deposition on surface water quality within the Big Bear Lake watershed warrant a more thorough investigation as part of the phased TMDLs.

Direct atmospheric loads to Big Bear Lake were estimated based on values reported in the literature for southern California mountain areas (BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003). Literature values for atmospheric deposition ranged from 25 to 35 kg N/ha/yr or 55 to 77 lbs N/ha/year at Camp Paivika in the western San Bernardino Mountains to 3 to 6 kg N/ha/yr or 7 to 13 lbs N/ha/yr at Barton Flats in the eastern San Bernardino Mountains (Fenn and Poth 1999).

Total phosphorus deposition was estimated at one-tenth of the total nitrogen load in the original nutrient budget study (BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003). For the WASP model setup (see Section 5.1), Tetra Tech (2004a) stated that this might be an overestimation due to the unusually high total nitrogen deposition in the area. Phosphate deposition is rarely measured and only nitrogen deposition rates were mentioned in the recent literature for the San Bernardino Mountains. Therefore, Tetra Tech did not use the deposition of phosphate in the WASP model setup. Based on the above-mentioned studies, it is estimated that the atmospheric loads to Big Bear Lake range from 5 to 30 kg N/ha/yr, or 11-66 lbs/ha/year. A total nitrogen atmospheric load of 10 kg/ha/yr, or 22 lbs N/ha/yr, was considered reasonable for this study because there is a dry deposition nitrogen gradient running from west to east in the San Bernardino Mountains, with higher values observed at the western end (Bytnerowicz and Fenn 1996). Since Big Bear Lake is located near the eastern end of the San Bernardino mountains, it seemed reasonable to use the values associated with the eastern end sites as opposed to the western end sites. Literature values suggest that total phosphorus output ranges between one-fiftieth and one-twentieth of the total nitrogen deposition rate (Holdren, Jones, and Taggart 2001, 16). The total phosphorus atmospheric load was set at one-twentieth of the total nitrogen load, or 1.1 lbs P/ha/yr. These estimated atmospheric loading rates include both dry and wet deposition. The estimated atmospheric loads for total N and total P under dry conditions (1999-2003) are 21,474 lbs/yr and 1,074 lbs/yr, respectively. The estimated atmospheric loads in a wet year are 23% higher than those in a dry year. It must be emphasized, however, that the loading rates that were used to calculate these estimates are based on limited information and need to be refined with empirical data for both wet and dry conditions.

[33] Confined Animal Feeding Operations

4.3 Internal Nutrient Loads from Sediment

Sediments serve as both a source and sink for nutrients and provide the principal mechanism for internal recycling of nutrients within Big Bear Lake (see Section 2.0). Sediment samples were collected from Big Bear Lake in 2002 and 2003 and the analyses included: 1)lake sediment characteristics; 2)sediment porewater properties; and 3)sediment nutrient flux rates. The results of these investigations have been summarized in two reports (Anderson and Dyal 2003; Anderson et al. 2004). It was found that nutrient flux rates varied spatially and temporally, with greater flux rates at the west end of the lake and in the summertime. This spatial variability in flux rates is important when considering and executing lake restoration activities. For example, for the lake-wide alum project conducted during summer 2004, alum application rates were adjusted to higher doses at the west end and lower doses at the east end[34]. It was also found that there is a spatial trend of increasing silt from west (MWDL1) to east (MWDL9) (Table 4-3). Similarly, data collected as part of the TMDL monitoring shows a spatial trend of increasing particulate phosphorus from west to east (Table 4-4).

Table 4-3. Sediment Characteristics of Big Bear Lake

Station	Sand (%)	Silt (%)	Clay (%)
MWDL1	79.3	7.3	13.4
MWDL2	72.8	14.1	13
MWDL6	73.5	16.2	10.3
MWDL9	57.4	30.5	12.1

Data Source: Modified from Anderson and Dyal (2003)

Table 4-4. Percentages of Dissolved Phosphorus (DP) and Particulate Phosphorus (PP) (2001-2003)

	Averages	
Station	**DP%**	**PP%**
MWDL1	46%	54%
MWDL2	46%	54%
MWDL6	41%	59%
MWDL9	34%	66%

As explained in Section 4.1, most of the sediment-related inputs to the lake occur during wet weather events and the highest loads come from granitic sands in forested areas. It is hypothesized that the apatite fraction of the granitic sands weathers within the lake and becomes bioavailable to the plants over time (BBMWD, Hydmet, Inc., and AquaTer, Inc. 2003). However, an alternative hypothesis is that the mineralization[35] of organic matter in the lake sediments occurs at a much faster rate than the weathering process, so that the process of mineralization has more effect on the diffusive flux of

[34] The application of aluminum sulfate (alum) to lakes is used to remove phosphorus from the water column (phosphorus precipitation), as well as to prevent phosphorus release from the sediments (phosphorus inactivation). Application of alum to lakes has been successful in decreasing total phosphorus concentrations and restoring beneficial uses.

[35] Mineralization is the conversion of organic forms into mineral or inorganic forms

nutrients from lake bottom sediments than does weathering (Tetra Tech 2004a). If apatite is not a source of readily bioavailable phosphorus for macrophyte uptake, then the total phosphorus load estimated by the HSPF model during extreme wet events (i.e., 1993) might consist of a majority of phosphorus that will only become bioavailable in the lake over the long-term. According to Anderson and Dyal (2003), soluble reactive phosphorus (SRP) fluxes occurred from mineralization or release from surficial material, not from material deeper in the sediments. Therefore, the 10 cm sediment cores collected in November 2003 are likely the best representation of sediment-phosphorus fractions that are important to the internal loading of phosphorus and to the growth of macrophytes within the lake. Data from these sediment cores were used to identify the fractions of phosphorus in the sediment for alum dosage considerations. The bioavailable forms of phosphorus are the loosely-bound P (i.e., $CaCO_3$-P and loosely sorbed P) and the iron-bound P fractions. The forms of phosphorus not easily transformed for uptake by biota are the aluminum-bound P and the calcium-bound (i.e., apatite) fractions. Residual-P is calculated by subtracting the various fractions from total P. The November 2003 data showed the highest fraction of calcium-bound phosphorus and loosely-bound P occurred at Station MWDL9, at the east end of the lake (Figure 4-5). The highest fractions of both aluminum-bound and iron-bound P were located at Station MWDL1. Sediment core flux studies conducted in 2002 (Anderson and Dyal 2003) and 2003 (Anderson et al. 2004) measured the highest flux rates of SRP at Stations MWDL1 and MWDL2 at the west end of the lake, and the lowest at the east end (Station MWDL9). From these data, it appears that iron-bound P drives the internal loading of phosphorus at the west end, while the loosely-bound P provides a readily bioavailable source of phosphorus for the macrophytes at the east end.

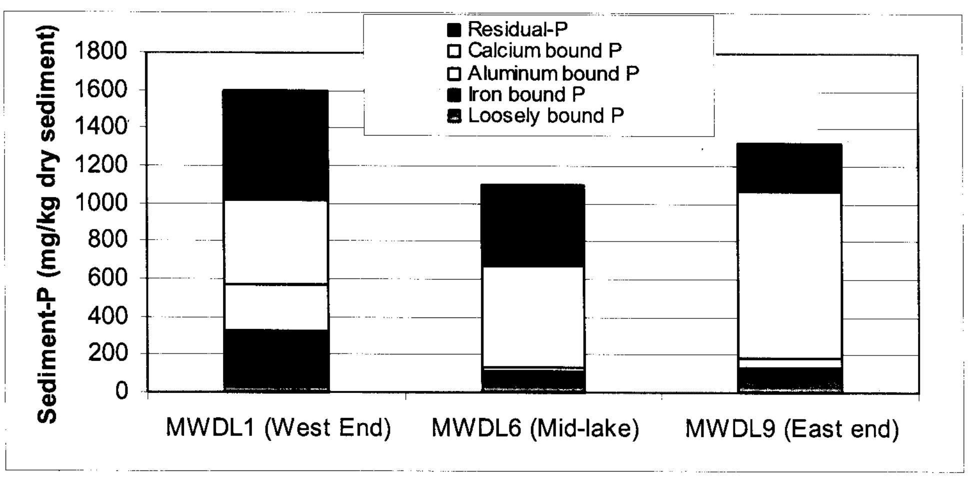

Figure 4-5: Average sediment-phosphorus fractionation for four types of sediment sources to Big Bear Lake, 11/6/2003

Tetra Tech (2004a) derived time functions to represent sediment fluxes as a function of either time of year or lake bottom depth for the WASP model. This enabled the proper characterization of sediments as a source of nutrients to the water column. Shown in Table 4-5 are sediment loads derived for each segment area for the period of record 1999-2003. These loads were derived by Tetra Tech (2004a) based on the work by Anderson and Dyal 2003 and Anderson et al. 2004. Anderson and Dyal (2003) and Anderson et al. (2004) provided seasonally-averaged nutrient loads for 6 months based on flux rates measured in summer-fall 2002 and 2003 and areas within each sediment depth zone[36].

Because of anoxic conditions at the sediment-water interface, the dominant form of nitrogen released from sediment is ammonium nitrogen (NH_4-N). The total loads for the 6 month summer-fall period in 2002 and 2003 were 105,311 lbs NH_4-N and 17,585 lbs soluble reactive phosphorus (SRP). Based on data collected by Anderson in 2003 to determine winter flux rates, staff estimated that during the remaining six-month period, the sediment nutrient flux is approximately 50% of the summer-fall NH_4-N load and 11% of the summer-fall SRP load. Based on these data, staff estimated total annual loads from sediment at 158,027 lbs NH_4-N and 19,436 lbs SRP. These loads are similar to the loads determined by Tetra Tech (2004a) (Table 4-5). Tetra Tech did not use the October 2003 sediment flux rates in their modeling effort because these rates were much higher in 2003 than in 2002 and could not be explained (Anderson et al., 2004)[37]. Because of the variation in flux rates from year-to-year, use of the average nutrient sediment loads over a 5-yr period as shown in Table 4-5 is appropriate for the nutrient budget. These values are 152,386 lbs NH4-N and 21,388 lbs SRP.

In addition to internal releases of nutrients, resuspension and sedimentation are important processes affecting in-lake nutrient concentrations. However, because of the complexity of these processes, sedimentation and resuspension of nutrients were not measured. Sedimentation[38] is the primary process affecting nutrient availability within Big Bear Lake during dry years, since watershed inputs of nutrients are minimal (Tetra Tech 2004a) (see Table 4-4). Model simulation of these processes indicates net settling velocities on the order of 75-102 m/yr depending on the constituent (Tetra Tech 2004a). These processes should be measured and the results included in any future modeling effort.

[36] Five sediment zones (e.g., A = depths > 33.6 feet) within the lake were defined by depth based on the location of the sediment sampling stations for the flux studies.

[37] Many restoration activities were initiated and carried out at the same time as sampling efforts continued for model development. These included the application of the herbicide Sonar and alum. For this reason, many anomalies in the sediment and water quality data cannot be explained. Variations in data could be due to lake level decreases, application of an aquatic herbicide, die-off of macrophytes, alum application or normal lake processes. More importance was placed on data acquired in 2001 and 2002, rather than 2003 when the effects of all ongoing restoration activities would have been maximized. Measurement of nutrient release rates from sediment continued in 2004 and 2005 and will continue as part of the TMDL implementation plan in order to determine the effectiveness of lake restoration projects designed to lower internal nutrient loads.

[38] Sedimentation is the deposition or settling of suspended material (both organic and inorganic) in water.

Table 4-5. Nutrient loads from sediment

SRP LOAD (LBS)	Dam	Open Water 1	Boulder Bay	Open Water 2	Metcalf Bay	Open Water 3	Grout Bay	Open Water 4	Main Bay	East End	Total
5-yr P load	851	16006	2403	25435	3601	19624	1217	16332	10927	10543	106938
Average per year	170	3201	481	5087	720	3925	243	3266	2185	2109	**21388**
% OF TOTAL AVG. LOAD PER YEAR	1%	15%	2%	24%	3%	18%	1%	15%	10%	10%	
1999	181	3309	544	5238	944	4088	417	3400	2421	2565	23107
2000	176	3266	524	5189	853	4042	357	3349	2367	2452	22575
2001	171	3218	501	5123	751	3974	275	3290	2276	2260	21838
2002	163	3125	435	4974	557	3800	107	3170	2000	1736	20067
2003	160	3089	399	4910	495	3720	61	3122	1863	1531	19351

AMMONIUM-NITROGEN LOAD (LBS)	Dam	Open Water 1	Boulder Bay	Open Water 2	Metcalf Bay	Open Water 3	Grout Bay	Open Water 4	Main Bay	East End	Total
5-yr N load	6147	115876	20492	175311	28347	123964	16671	97704	84711	92709	761932
Average per year	1229	23175	4098	35062	5669	24793	3334	19541	16942	18542	**152386**
% OF TOTAL AVG. LOAD PER YEAR	1%	15%	3%	23%	4%	16%	2%	13%	11%	12%	
1999	1309	23946	4646	36094	7435	25819	5707	20332	18772	22561	166622
2000	1271	23657	4472	35787	6697	25547	4867	20044	18354	21536	162233
2001	1233	23280	4267	35289	5891	25085	3722	19670	17614	19796	155847
2002	1177	22635	3717	34306	4430	24027	1535	18982	15547	15381	141736
2003	1157	22358	3391	33835	3895	23488	840	18675	14423	13433	135494

Data source: Analysis and summary prepared by Tetra Tech, 2004a with data supplied by Anderson and Dyal (2003) and Anderson et al. 2004

4.4 Internal Nutrient Loads from Macrophytes

Aquatic macrophytes are both sources and sinks of nutrients. During fall, when macrophytes die-off and decay, nutrients are released back into the water column and to the sediment through macrophyte decomposition[39]. At other times, macrophytes obtain nutrients from the water column and/or from the sediment, depending on the species. This process can reduce the amount of nutrients in the water column that would be available for planktonic algae growth.

Plant biomass and plant tissue nutrient concentrations were measured to estimate the contribution of aquatic macrophytes to the internal nutrient load. Plant tissue samples were collected on two occasions in 2002 and analyzed for nitrogen and phosphorus content. Biomass samples were obtained in 2002 and 2003. Samples were collected from areas that had not received treatment with the aquatic herbicide, Sonar PR. Plant tissue collection efforts and locations are described in BBMWD, Hydmet, Inc, and AquAeTer, Inc. (2003). Locations of plant biomass stations as well as the plant biomass data collection methodology are described in BBMWD and ReMetrix (2004). The results of all the vegetation assessments performed by ReMetrix from 2002-2003 were used by Tetra Tech (2004a), with some additional manipulation, for input into the WASP lake model. Due to the way in which the biomass samples were collected, it was postulated by Tetra Tech that the actual biomass was higher than that measured; thus, Tetra Tech (2004a) used three times the average calculated volumetric density in their calculations[40]. These numbers should be refined with future macrophyte assessments.

Shown in Table 4-6 are the total macrophyte biomass and total macrophyte nitrogen and total macrophyte phosphorus nutrient standing stocks in Big Bear Lake as calculated by Tetra Tech (2004a). As shown in Table 4-6, macrophytes represent a significant source and sink of nutrients in Big Bear Lake.

Table 4-6. Total estimated peak annual macrophyte biomass and nutrient standing stocks (Tetra Tech, 2004a)

Year	Total Macrophyte Biomass (lbs)	Total Macrophyte Nitrogen* (lbs)	Total Macrophyte Phosphorus* (lbs)
1999	4,885,996	92,345	14,169
2000	5,989,631	113,205	17,371
2001	6,698,234	126,596	19,424
2002	6,754,230	127,654	19,587
2003	6,608,905	124,909	19,166
Average	**6,187,399**	**116,942**	**17,943**

*based on plant tissue measurements (BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003)

[39] These releases of nutrients are mitigated by uptake by epiphytic bacteria and algae (Wetzel 2001, 546). Similarly, macrophytes act as large reservoirs of nitrogen and phosphorus, immobilizing the nutrients into tissues (Wetzel 2001, 215, 254).

[40] Plant biomass samples were calculated by the rake method. However, this method might have underestimated the true biomass of samples, especially with respect to the free-floating macrophyte, coontail, which might not be captured by the rake. Calculated volumetric density ranged from 287.1 to 5414 g/m^3, with an average of 1571 g/m^3. Three times this average, or 4713 g/m^3, was used in the WASP model. Two macrophyte biomass control samples obtained prior to the 2002 Sonar treatment had densities that were above the calculated average (2029 and 3885 g/m^3). For discussion on the macrophyte modeling, please see Tetra Tech (2004a).

4.5 Summary of Nutrient Loads from All Sources

Table 4-7 summarizes the sources and the corresponding annual average loads for the dry period 1999 to 2003 for HSPF-simulated watershed sources, atmospheric deposition, sediment and macrophyte sources to Big Bear Lake. This information is also shown graphically in Figures 4-6 and 4-7. Sedimentation and resuspension of nutrients were not determined for this nutrient budget, although in the future they should be measured and incorporated into the nutrient budget.

Also shown in Table 4-7 are the total loads under an extreme wet event (1993), and the annual average loads for the period 1990-2003, which incorporates all types of hydrological scenarios. These loads are shown for comparison purposes only. Note that macrophyte and sediment loads are constant for all these scenarios because there are no relevant data for extreme wet or average hydrological events.

As shown in Figures 4-6 and 4-7, for the dry period 1999-2003, the average nutrient loads from the sediment and macrophytes is approximately 91% of the total nitrogen load and 96% of the total phosphorus load. As can be expected, external nutrient loads are the driving force for total phosphorus loading to Big Bear Lake during a wet year, providing approximately 71% of the total phosphorus loads. Total nitrogen loads contributed from internal sediment and macrophyte loads during a wet year are still the primary source of nitrogen to the lake (64%). During average hydrological events, internal nutrient loads dominate, contributing 86% of the total nitrogen loads and 78% of the total phosphorus loads to the lake.

In all modeled scenarios, atmospheric deposition contributes less than 3% of the total phosphorus load and less than 8% of the total nitrogen load. As stated previously (Section 4.2), these values need to be compared to empirical data because the San Bernardino Mountains have some of the highest nitrogen loading rates in the country.

Macrophytes contribute a significant percentage of the total nutrient load (40% of TN load and 44% of TP load on average) during dry conditions, and are expected to remain a significant source of nutrients. As discussed in Section 3.1.2, staff assumes that a diverse community of macrophytes is necessary to maintain a balanced aquatic ecosystem. As such, it is expected that there will always be seasonal die-off of macrophytes, resulting in the release of nutrients to the water column or to the bottom sediments.

Table 4-7. Total nutrient loads to Big Bear Lake from all sources (lbs/year) (CY)

Parameter	Atmospheric Load[1]	Forest Nonpoint Source Load[2]	Resort NPS Load[3]	Urban Point Source Load[4]	Macrophyte Internal Load[5]	Sediment Internal Load[6]	Total Measured Load[7]
DRY SCENARIO 1999-2003 AVERAGE							
TOTAL NITROGEN	**21,474**	**460**	**811**	**3,445**	**116,942**	**152,386**	**295,518**
% OF TOTAL	**7.3%**	**0.2%**	**0.3%**	**1.2%**	**39.6%**	**51.6%**	**100.0%**
TOTAL PHOSPHORUS	**1,074**	**175**	**33**	**475**	**17,943**	**21,388**	**41,088**
% OF TOTAL	**2.6%**	**0.4%**	**0.1%**	**1.2%**	**43.7%**	**52.1%**	**100.0%**
AVERAGE SCENARIO 1990-2003 AVERAGE							
TOTAL NITROGEN	22,184	3911	5,204	12,572	116,942	152,386	313,199
% OF TOTAL	7.1%	1.2%	1.7%	4.0%	37.3%	48.7%	100.0%
TOTAL PHOSPHORUS	1,109	5,425	503	3,848	17,943	21,388	50,181
% OF TOTAL	2.2%	10.7%	1.0%	7.7%	35.8%	42.6%	100.0%
WET SCENARIO (1993)							
TOTAL NITROGEN	24,149	25,478	31,504	73,764	116,942	152,386	424,223
% OF TOTAL	5.7%	6.0%	7.4%	17.4%	27.6%	35.9%	100.0%
TOTAL PHOSPHORUS	1,207	60,325	5,057	32,628	17,943	21,388	138,548
% OF TOTAL	0.9%	43.5%	3.6%	23.5%	13.0%	15.4%	100.0%

[1] Atmospheric loads calculated for each year adjusting for lake areas; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 used for dry event
[2] Forest nonpoint source load = HSPF simulated loads from Forest North and Forest South land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[3] Resort nonpoint source load = HSPF simulated loads from Resort land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[4] External point source load = HSPF simulated loads from residential and high density urban land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[5] Macrophyte internal loads developed from data collected by BBMWD, Hydmet, Inc., and AquAeTer, Inc. 2003; ReMetrix 2004; and analyzed and interpreted by Tetra Tech 2004a
[6] Sediment internal loads developed from data collected by Anderson and Dyal 2003; Anderson et al. 2004 and analyzed and interpreted by Tetra Tech 2004a
[7] Total measured load = sum of items 1-6

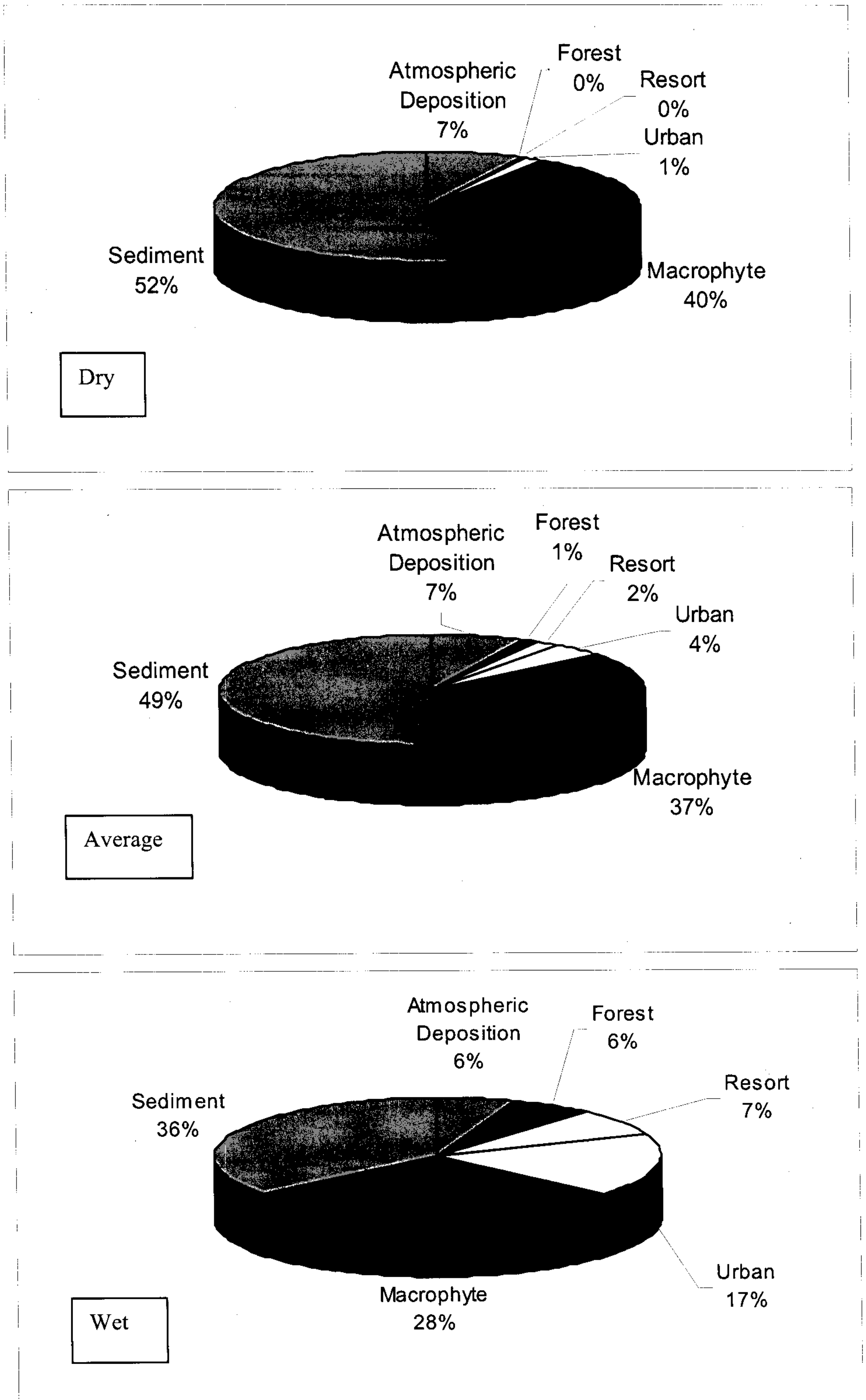

Figure 4-6. Total nitrogen load to Big Bear Lake under three conditions: dry year-average of years 1999-2003; average of years 1990-2003; wet year (1993)

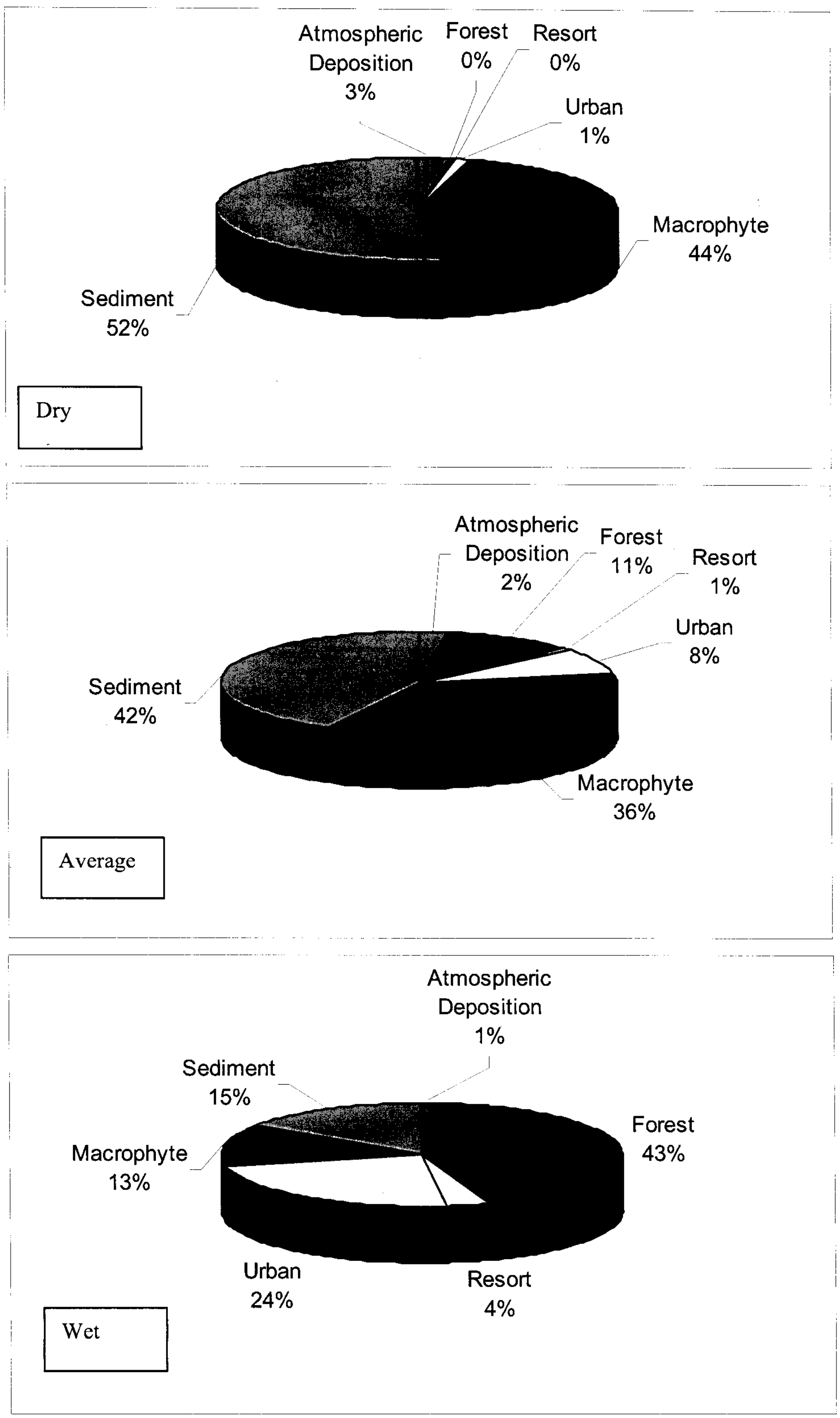

Figure 4-7. Total phosphorus load to Big Bear Lake under three conditions: dry year-average of years 1999-2003; average of years 1990-2003; wet year (1993)

5.0 LINKAGE ANALYSIS AND TMDL (LOAD CAPACITY)

As stated by the USEPA (1999), the linkage analysis is an essential component of the development of a TMDL. A link needs to be established between predicted nutrient loads and the selected numeric target(s) chosen to measure the attainment of beneficial uses. This linkage allows determination of the nutrient loading assimilative capacity of the impaired water, and the amount of loading reduction needed. The nutrient loading assimilative capacity of lakes and requisite loading reductions typically vary with lake levels, which reflect different hydrologic conditions.

The relationship or link between the selected numeric target(s) and the predicted nutrient loads can be determined using a combination of monitoring data, analytical tools (including models), and best professional judgment (USEPA 1999). Ideally, a long-term monitoring data set, with different flow regimes and nutrient loads, would be available for the body of water in order to determine the load capacity under various hydrological regimes.

5.1 Big Bear Lake Water Quality Analysis Simulation Program (WASP6) Model for Total Nitrogen and Total Phosphorus

In order to determine the phosphorus and nitrogen TMDL (load capacity) for Big Bear Lake, the WASP6 model was chosen based upon the available monitoring data, resources for the application, and the time frame available for modeling. The WASP model is an USEPA approved model for TMDL development for receiving water bodies. "WASP6 is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. WASP allows the user to investigate 1, 2, and 3 dimensional systems, and a variety of pollutant types. The time varying processes of advection, dispersion, point and diffuse mass loading and boundary exchange are represented in the model. WASP also can be linked with hydrodynamic and sediment transport models that can provide flows, depths, velocities, temperature, salinity and sediment fluxes" (USEPA 2004). WASP6 includes a pre-processor, WASP eutrophication and organic chemical model processors and a graphical post-processor that enables the results of the WASP model to be compared to the observed field data. The WASP model is comprised of a set of mass balance equations, user-specified input data describing the transport of mass throughout the system, and the rates and constants used in the chemical kinetics equations, all of which are all numerically integrated over time.

The Big Bear Lake WASP water quality model developed by Tetra Tech, Inc. (2004a) includes a hydrodynamic linkage file, a nonpoint source loading file that was created from the HSPF loads (see Section 4), predicted macrophyte nutrient loads and sediment nutrient loads[41] (Figure 5-1). The lake was divided into ten segments to best represent lake dynamics (Figure 5-2). Calibration of total nitrogen and total phosphorus concentrations show that model results match seasonal trends for these constituents (Tetra Tech 2004a).

The model was used to project in-lake nutrient and chlorophyll *a* concentrations resulting from different strategies for managing external and internal nutrient loads. These scenarios and the model results are presented in Table 5-1. The nutrient load capacity of Big Bear Lake, under dry conditions

[41] The sediment nutrient fluxes were incorporated in the WASP model in the segment parameters group. There were spatial differences as well as depth differences in the sediment nutrient fluxes measured at four stations in the lake that had to be taken into account when modeling. For a more detailed description of how these differences were incorporated into the final input parameters of the WASP model, and for a discussion of other aspects of the model setup and assumptions, please consult the WASP modeling report prepared by Tetra Tech (2004a).

only (see below), was determined from the model results that matched the proposed nutrient numeric targets (discussed in Section 3.0)[42]. The results for model runs 20, 20a, 20b, 20d, and 24, indicate that the interim total phosphorus and chlorophyll *a* numeric targets are achieved if phosphate flux is reduced from 50-80% and macrophyte loads are reduced from 10-50%. Model runs 20c, 21b, 22b, 23, and 26a also result in compliance with the interim total phosphorus and chlorophyll *a* numeric targets, but in addition to phosphate flux and macrophyte load reductions, ammonia flux must be reduced from 50-80%. The results for model runs 20b and 20c suggest that in order to meet the final total phosphorus and chlorophyll *a* targets, phosphate loads must be reduced by at least 80% and macrophyte loads by 50%. Model run 20c also includes an 80% reduction in ammonia sediment flux , resulting in total nitrogen concentrations that are closer to the proposed final numeric target (1000ug/L). However, no model simulation resulted in compliance with this numeric target. As discussed below, this is likely attributed to model limitations and incomplete understanding of macrophyte nutrient dynamics in the lake.

It is essential to bear the following points in mind when reviewing the results presented in Table 5-1:

a. *Dry Condition Simulations*

First, **the WASP model cannot be used to predict water quality conditions in Big Bear Lake during wet or average years, since the period for which the model simulation occurred (1999-2003[43],) was characterized by extremely dry conditions.** Thus, the WASP model results can be used to establish the load capacity (TMDL) only for dry conditions. For the purposes of these TMDLs, dry conditions are defined as 0-23 inches of precipitation, 0-3049 AF of inflow and lake levels ranging from 6671 – 6735 feet. These values represent the ranges of lake metrics observed for the 1999-2003 period.

As discussed in Section 2, there are historical water quality data for Big Bear Lake that include wetter conditions, however much of these data were found to be unusable for modeling purposes, primarily because of insufficient detection limits. It is recognized that external nutrient loads are greatest during wet years, and that the effects of inputs at those times are manifested in the lake for an extended period (the residence time of water in the lake is 11 years, and sediment and macrophytes serve as nutrient reservoirs). It is apparent that a high quality, long-term monitoring program is needed to collect this type of data for Big Bear Lake. With these data, the WASP model can be refined to simulate lake water quality during wet and average conditions and to make recommendations for appropriate TMDLs. The implementation of such a monitoring program is an important component of the proposed Implementation Plan (Section 10).

The model simulations presented in Table 5-1 show that any reduction in external loads will not change the predicted water quality concentrations in Big Bear Lake. These results are not unexpected, given that WASP was calibrated only for dry conditions, when internal nutrient loads predominate (see Section 4.5). The model results show that during dry years, there is no justification to require a reduction in external loads; rather, the focus must be on reducing internal loads. It would be inappropriate to conclude, however, that no reductions in external loads would be required under

[42] As discussed in detail later in this section, none of the model simulations resulted in compliance with the proposed final total nitrogen target. Staff believes that this reflects model limitations that are to be addressed as part of the proposed Implementation Plan for this TMDL (see Section 10).

[43] All lake quality-related data used in the model were collected from 2001-2003. The water balance component of WASP used lake levels monitored at the dam from 1999 –2003. HSPF model output was also available for this period. For modeling purposes, plant biomass and sediment flux rates measured in 2002 and 2003 were used also for 1999, 2000 and 2001, since dry conditions prevailed throughout this period.

different hydrologic conditions. As discussed in Section 4.5, external sources contribute large nutrient loads during wet years. The model is not yet calibrated to assess loading capacity, and requisite nutrient load reductions, under those conditions. This deficiency is addressed in the recommended Implementation Plan for this TMDL (see Section 10).

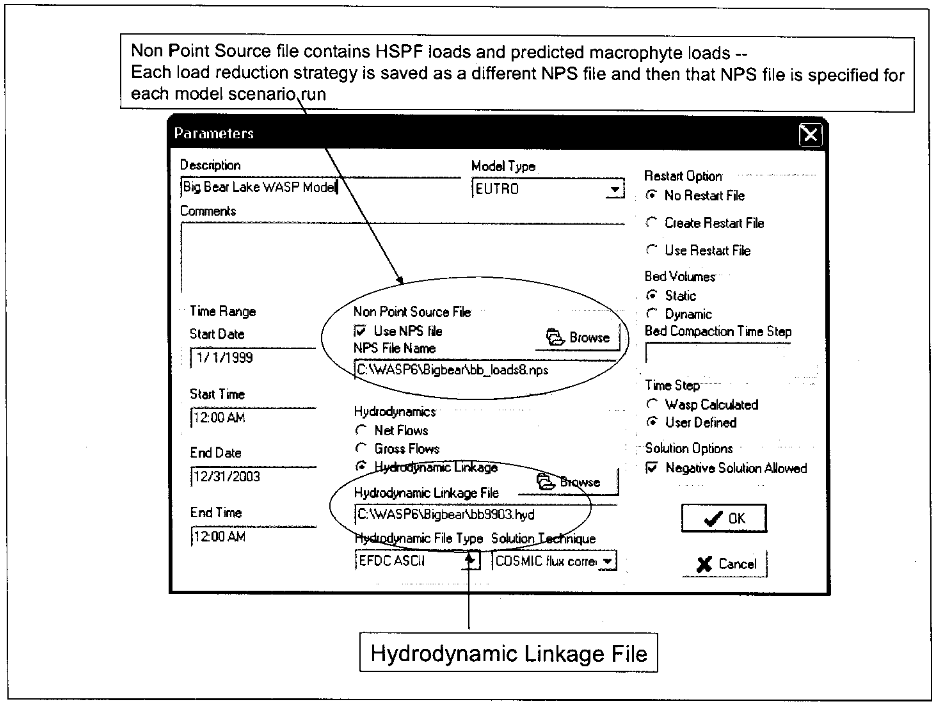

Figure 5-1. WASP Model Interface

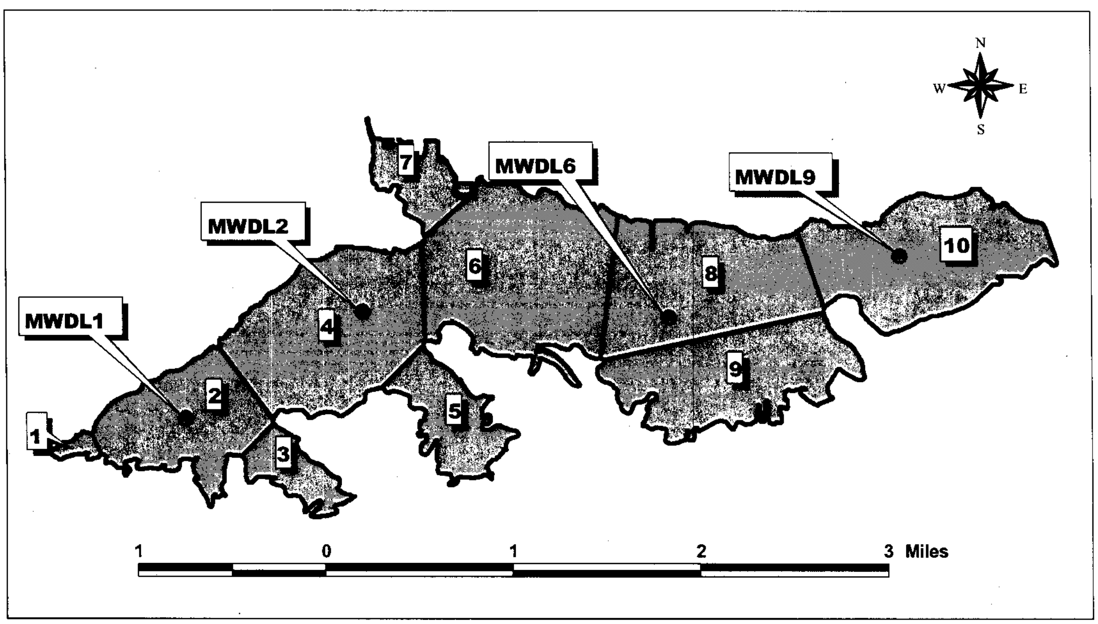

Figure 5-2. WASP segments for Big Bear Lake (Tetra Tech 2004a)

b. *Macrophyte Dynamics*

Second, WASP efforts were constrained by the model's inability to simulate macrophyte nutrient dynamics. Rather, various assumptions regarding macrophyte nutrient loads, rates of uptake and release, etc. had to be simulated via nonpoint source files entered into the model. Each nonpoint source file is essentially a spreadsheet that runs the HSPF and macrophyte load reductions independently of WASP. For each load reduction strategy, a separate nonpoint source file is created that contains the final loads assumed to be contributed by macrophytes and external loads (i.e., HSPF output). The nonpoint source file is then specified in the WASP model interface (see Figure 5-1). As the WASP model is run, it uses the input from the specified nonpoint source file to simulate nutrient processes and output nutrient concentrations.

Figure 5-3 shows the assumptions of macrophyte uptake, re-burial of nutrients (via macrophyte decay) and release of nutrients by macrophytes to the water column that were used in each of the nonpoint source files. Specifying certain percentages of macrophyte uptake, re-burial and water column release of nutrients in the spreadsheet allows the model to be run, but does not reflect the dynamic interrelationships between sediment, water column and macrophytes.

These limitations placed constraints on the loading reduction strategies that could be simulated by WASP. In order to perform the simulations, assumed nutrient loads from macrophytes, input via the nonpoint source files, had to be reduced to enable sediment fluxes to be reduced beyond 50%. This reflects the interconnection recognized in the model (though not simulated dynamically) between sediment releases of nutrients and macrophyte growth. The model recognizes that if sediment nutrient fluxes are reduced, the nutrient loads to the water column would be reduced and there would be less phytoplankton growth (which is simulated by the model) and less assimilation of nitrogen and phosphorus into organic matter. Less organic matter would result in less settling that would deliver nutrients to the sediments. The result would be a decrease in the amount of nutrients recycled from the sediments back into the water column as well as a decrease in nutrient sediment concentrations used for macrophyte growth. Because macrophytes would use nutrients from the water column and from the sediment for growth, any significant reduction in sediment nutrients has to be accompanied in the model simulations by assumed reductions in macrophyte growth and the nutrient loads that those macrophytes would ultimately contribute to the system. If phosphate fluxes were assumed to be reduced by 60%, macrophyte loads had to be reduced by at least 10%. If phosphate fluxes were reduced by 70%, macrophyte loads had to be reduced by at least 25% and if phosphate fluxes were reduced by 80%, macrophyte loads had to be reduced by at least 50%[44]. Staff does not recommend a change in the macrophyte coverage in the lake, only different species composition (see Sections 3.1.2 and 3.1.3). However, a change in macrophyte coverage, and thus macrophyte nutrient loads, had to be assumed for modeling purposes[45].

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[44] Note that the model would not run with phosphate fluxes reduced by 80% and macrophyte loads reduced by 25%. Assumed macrophyte loads between 25 and 50% might allow model simulations with the concomitant assumption of an 80% reduction in phosphate fluxes, but these simulations were not performed.

[45] Staff recognizes that a dramatic decrease in sediment flux rates might result in a decrease in macrophyte growth and coverage. Correlations between macrophyte growth and coverage and sediment flux rates, as well as nutrient water column concentrations can only be made with future monitoring as proposed in the Implementation Plan for this TMDL (see Section 10).

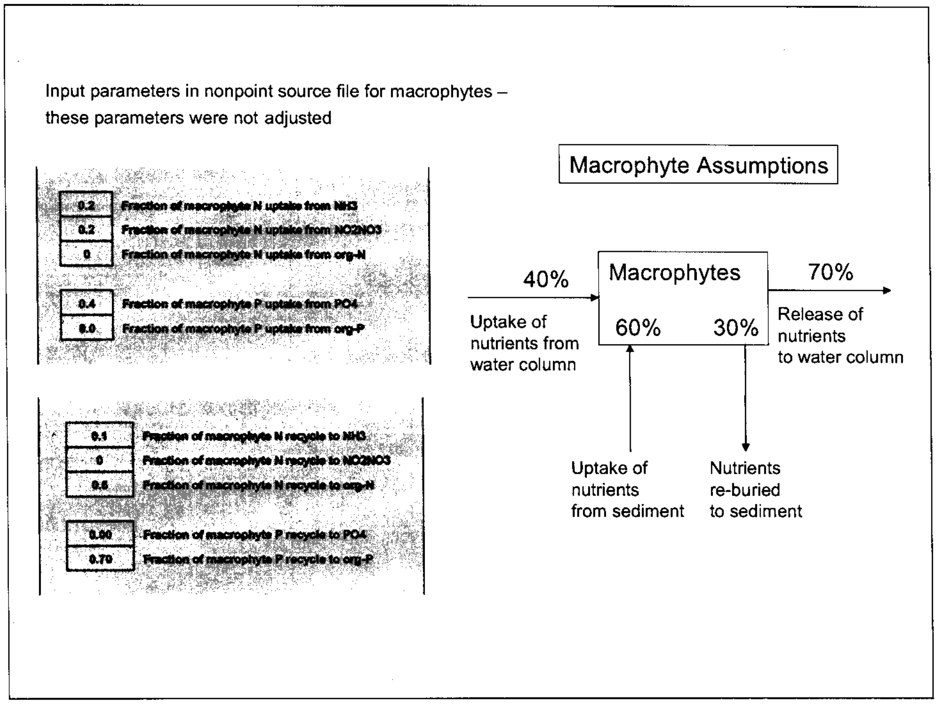


Figure 5-3. Macrophyte assumptions

The lack of macrophyte nutrient dynamic modeling capability also affects significantly the model projections of total nitrogen quality. If phosphate flux reductions are made, with concomitant macrophyte load reductions where necessary to run the model, the total nitrogen concentrations increase significantly (see, for example, the results of model runs 20, 20a 20b, and 20d in Table 5-1). In the model simulations, this results from less phytoplankton growth due to the reduced phosphorus flux (the lake is generally phosphorus limited (Section 3.1)) and less assimilation of nitrogen in the water column into organic matter. Settling that would result in removal of nutrients from the water column to the sediment would also decrease in the simulations. In reality, however, floating macrophytes would be expected to remove some of this water column nitrogen and rooted macrophytes might also remove some of this nitrogen, as long as there are adequate nutrients in the sediment to sustain their growth. The inability to model this process reflects both model limitations and data gaps with respect to current knowledge of macrophyte nutrient dynamics (Tetra Tech 2004a).

The results of the lakewide TMDL monitoring and nutrient sediment flux studies were evaluated to assess the validity of the high total nitrogen concentrations predicted in model scenarios in which phosphate flux was reduced. As previously described (Section 4.3), aluminum sulfate (alum) is applied to lakes to remove phosphorus from the water column (phosphorus precipitation), as well as to prevent phosphorus release from the sediments (phosphorus inactivation). A trial alum project was conducted in an isolated area of Big Bear Lake (Papoose Bay) in October 2003. Monitoring results showed more than a 90% reduction in SRP fluxes from the sediment, and greater than 50% increases in ammonia flux from the sediment. Alum was applied lakewide (with the exception of the east end) in May-June 2004. SRP flux rates from the sediment were reduced by more than 80% in the areas that were treated. Total phosphorus and total nitrogen data from this period and extending back to 2001 to include two applications of the herbicide Sonar (in 2002 and 2003) are shown graphically in Figure 5-4. These results show that total nitrogen concentrations continually and gradually increase from 2001 through 2004. However, the maximum total nitrogen concentrations observed after the lakewide alum project are significantly less than the levels predicted in model simulations that assumed reduced phosphate sediment flux. The inability to model macrophyte nutrient dynamics clearly limits confidence in the total nitrogen results produced by the model simulations. It is also likely that the inability to identify a simulation strategy that would achieve compliance with the proposed final numeric total nitrogen target can be attributed to this model deficiency. While **interim and final numeric targets for total nitrogen were considered initially, it became clear that this model deficiency would need to be addressed to support their propriety. No interim total nitrogen target is proposed. However, in conformance with relevant federal regulations, a final total nitrogen target is specified, with an extended compliance schedule. The intent is to provide time necessary to refine the model and obtain data necessary for calibration. This is a task identified in the proposed Implementation Plan (Section 10).**

c. Macrophyte Density Assumptions

Finally, it must be recognized that the density of macrophytes in the water column used in the model simulations was estimated to be three times the average of that previously measured and reported by BBMWD, Hydmet, Inc., and AquAeTer, Inc., 2003 (Tetra Tech 2004a). This was because of uncertainties regarding the accuracy of the rake method used to calculate biomass samples (see also Section 4.4)[46]. In addition, the model calibration determined that this was the best fit. This larger estimation might have resulted in an overestimate of the actual macrophyte biomass and corresponding nutrient loads, although the calculated density (i.e., 4713 g/m^3) is within the range of observed densities (i.e., 287 to 5414 g/m^3). Macrophyte density can be adjusted in the nonpoint source input files, however, staff did not adjust this parameter because it would have involved re-calibrating the model. As described below (see "Conclusions"), these uncertainties regarding the density of observed macrophytes affected staff's recommendations regarding nutrient management strategies.

d. Feasibility of Nutrient Reductions Simulated by WASP

It is reasonable to question the technical feasibility of achieving the nutrient load reductions assumed in the WASP model runs. (Economic and other practical considerations of implementing the reductions are addressed in Section 11).

First, with respect to sediment nutrient flux, the reductions assumed were based on literature values for specific lake restoration activities. The application of alum to lakes has been successful in decreasing total phosphorus concentrations and restoring the beneficial uses. Welch and Cooke (1995) report total phosphorus summer reductions ranging from 54% to 80% after phosphorus inactivation in the sediments that lasted from 7-10 years. Eight lakes averaged a 52% total phosphorus reduction after phosphorus inactivation that lasted eight years or more (Welch and Jacoby, 2001).

The results from the trial alum project in Papoose Bay conducted in October 2003 show that SRP fluxes were reduced by more than 90% immediately after the treatment and reduced by approximately 60% a year after the initial treatment. Results from the lakewide alum project conducted in May-June 2004 show that SRP fluxes were reduced by 93%, 84%, and 82% at Stations MWDL1, MWDL2,

[46] To summarize, the rake method used to calculate plant biomass samples might have underestimated the true biomass of samples. Density of plants was calculated by using the biomass of plants measured in kg/m^2 divided by the plant height in meters, which was derived from the estimated depth (Tetra Tech 2004a).

MWDL6, respectively. A smaller reduction (45%) was also seen at Station MWDL9, located at the east end of Big Bear Lake, even though no alum was applied in the area[47]. This reduction might be attributed to the prevailing winds from the west, which would have carried alum suspended in the water column to this station (Berkowitz and Anderson 2005, 23) So, even though the east end received no direct alum treatment it appears to have benefited from the treatment elsewhere in the lake.

Water column concentrations measured after the conduct of the lakewide alum application in Big Bear Lake during the months of May and June 2004 show a decrease in total phosphorus by an average of 41% in the areas that received alum treatment versus 16% for the east end, which did not receive alum directly. Similarly, chlorophyll *a* concentrations were reduced on average by 31% in the areas that received alum treatment versus a 38% increase for the east end. Total nitrogen concentrations increased an average of 4%. Total phosphorus concentrations after the 2004 lakewide alum treatment are near the concentrations observed in 2002 after the initial Sonar treatment (Figure 5-4b). Macrophytes were not removed from the lake after both the 2002 and 2003 Sonar treatments and likely served as a source of nutrients to algae and to the water column. Another application of Sonar in 2003 further reduced macrophyte biomass, but also removed a sink of nutrients. The effects of the decaying biomass from 2002, as well as lower lake levels (Figures 5-5 and 5-6) are most likely the causes of the decrease in lake water quality seen in 2003. Judging from the increases in chlorophyll *a* concentrations observed at MWDL9, if alum had not been applied lakewide, it is very likely that algae blooms would have been more prolific in 2004, with a corresponding decrease in lake water quality. Alum dosages for Big Bear Lake, and the longevity of the alum application (higher doses results in a longer period of phosphorus inactivation), were based on the money available. It would require a dose of alum 10-times greater than that received in 2004 to inactivate the entire sediment phosphorus pool (BBMWD 2005, 24).

Dredging of the bottom sediments would remove adsorbed nutrients from the system, reducing sediment flux and the growth of algae. Deepening of selected areas by dredging should be effective in controlling macrophytes by limiting the light available for their growth. Macrophytes generally grow in less than 20 feet of water. In one lake, a 90% reduction of total phosphorus and an 80% reduction in total nitrogen were observed when sediment removal occurred (Welch and Cooke 1995). A pilot-scale dredging project for the east end of Big Bear Lake commenced in April 2005. Monitoring will determine the nutrient loads removed by the dredge project and the changes in nutrient flux rates after the dredge project. Until that time, the only available efficacy rates for nutrient removal due to dredging are those in the literature. It can be noted that no whole lake dredging has been proposed for Big Bear Lake, only dredging within selected areas that would improve navigation, reduce macrophyte growth, increase recreational access and improve fisheries habitat in localized areas.

Artificial circulation and hypolimnetic aeration are also methods used to reduce lake stratification and increase dissolved oxygen concentrations at the lake bottom. Increasing dissolved oxygen concentrations decreases sediment nutrient fluxes. Since the 1980s, several aerators have been in operation in Big Bear Lake near the dam. According to the BBMWD, these have had a positive effect on lake water quality, however no data exist to quantify the efficacy of the aerators in reducing whole lake total phosphorus and total nitrogen concentrations. Hypolimnetic aeration has been successful in reducing whole lake total phosphorus by 70% in two lakes for at least one or two years (Welch and Jacoby 2001).

[47] A revision to the calculations used to determine the volumetric dose of alum was made on the third day of application, which resulted in a shortage of alum. Therefore, alum was not applied to the shallow east end since this area was going to be dredged in 2005 (BBMWD 2005, 9).

Based on the studies described above, a 50-80 percent reduction in internal total phosphorus loading from the sediment appears to be technically feasible.

As discussed in "b", above, reductions in macrophyte nutrient loads are tied to reduction of the sediment flux of phosphate in the model. To the extent that such reductions are effective, they are likely to be the most efficient as well. The application of Sonar or other aquatic herbicides, as well as physical harvesting, reduces macrophyte coverage and associated nutrient loads. However, herbicide reapplication would likely be necessary on a periodic basis, depending on the success of phosphate reduction or other nutrient control strategies. Similarly, repeated physical harvesting has been necessary and has the added disadvantages of potentially spreading fragments of nuisance species to other areas and causing disturbance to bottom dwelling organisms. Dredging can also reduce macrophyte biomass and associated nutrient loads if conducted to depths greater than 10 feet (see Table 2-5).

The technical feasibility of external load reductions is not considered here. As noted previously, because of the dry conditions simulated by the model, changes in external loads have no effect on resultant total nitrogen and total phosphorus concentrations in the lake. Accordingly, no external load reductions are recommended by staff as part of this TMDL (see Sections 5.2 and 6.0). The technical and economic feasibility of reducing external loads will need to be examined once the model is calibrated to address the wet conditions that result in significant external nutrient loading to the lake, and as recommendations for a TMDL and wasteload/load allocations based on those conditions are developed.

Conclusions

The results of simulations of model runs 20, 20a, 20b, 20d, and 24 suggest that the proposed interim total phosphorus and chlorophyll *a* targets can be achieved by various combinations of phosphate flux reductions of 50% or more and macrophyte load reductions from 10-50%. Staff considered the factors described in a-d, above, in recommending the appropriate combination of such reductions to calculate the load capacity that meets the interim total phosphorus and chlorophyll *a* numeric targets (see Section 5.2). Specifically, staff recommends that the reduction assumptions in model run 20a be used to calculate load capacity for the interim targets, i.e., a 60% reduction in phosphate sediment flux and a 25% reduction in macrophyte phosphorus and nitrogen loads (the 25% reduction is assumed to be split evenly between phosphorus and nitrogen)[48].

As discussed in Section 3.1.2, for a healthy lake ecosystem, staff believes that macrophyte coverage should range from 30-60% on a total lake basis. Different percentages of macrophyte coverage would result in varying levels of nutrient loads[49]. Staff does not propose any reductions in macrophyte coverage but, rather, changes in species composition (Sections 3.1.2 and 3.1.3)[50]. However, as discussed in "b", above, for the model to run, it is necessary to assume a reduction in macrophyte loads. Because of uncertainties in the measured density of the macrophytes (Section 4.4), the possibility that macrophyte loads might be overestimated in the model simulations (see "c", above), and uncertainties regarding the assumptions used in the nonpoint source file for macrophyte uptake

[48] The uptake of these nutrients was specified evenly between nitrogen and phosphorus in the nonpoint source file.
[49] Note that there are no studies that currently show correlations between water column concentrations and macrophyte coverage, or correlations between sediment nutrient flux reductions and macrophyte coverage. Further research might identify such correlations.
[50] Briefly, Staff's proposed approach is to ensure a more balanced, diverse macrophyte community –one that is not dominated by the noxious aquatic plant Eurasian watermilfoil and the nuisance plant coontail.

and re-burial of nutrients, the assumption of a 25% reduction in nutrient loads from macrophytes for the proposed **interim** numeric targets, split evenly (12.5%) between total N and total P appears to be reasonable and appropriate.

Model run 20b suggests that phosphate loads have to be reduced by at least 80% and macrophyte loads by 50% in order to meet the final total phosphorus and chlorophyll *a* targets. For the reasons just described, staff again believes that it is appropriate to assume a macrophyte nutrient load reduction of 25% (12.5% P and 12.5% N), rather than 50%, to meet the proposed final targets. Because of model limitations, this management scenario could not be evaluated using WASP. This deficiency is to be addressed as part of the proposed Implementation Plan and changes to the recommended macrophyte load strategy (and TMDL) can be made based on that effort. It should be emphasized that the WASP model simulations described in this report represent the initial effort to predict water quality concentrations after implementing lake management strategies, such as alum application and dredging. The actual effect of implementation of these strategies on macrophyte growth will be determined through appropriate monitoring. Those results will be used to make appropriate revisions to the model assumptions and TMDL.

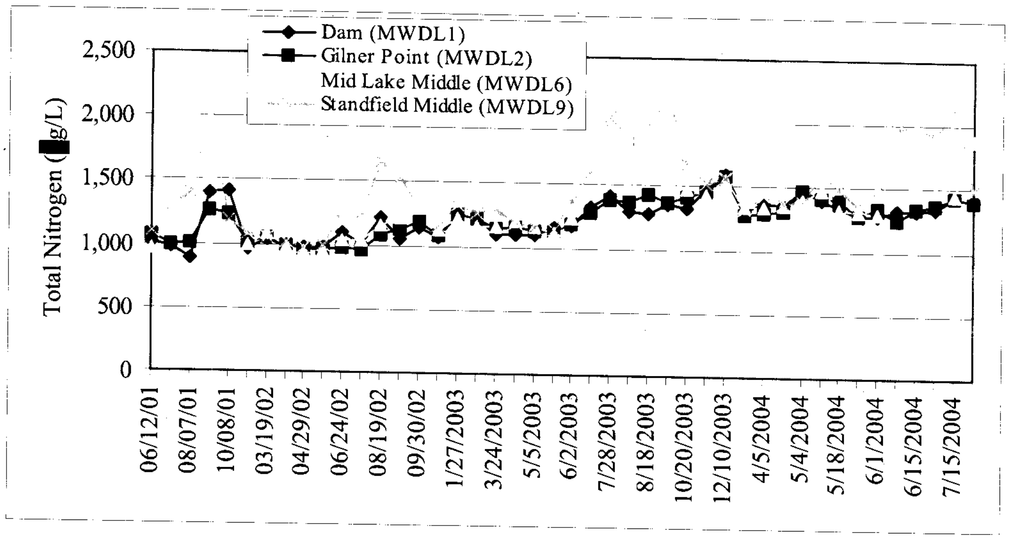
Model run 20c, with an assumed 80% reduction in ammonia flux, shows lower projected lake nitrogen concentrations. Without a lake-wide dredging project, such a reduction in ammonia flux is not likely. Even with this assumed reduction, however, the predicted nitrogen concentration of 2700 μg/L still does not meet the proposed final nitrogen target of 1000 μg/L. Again, no nutrient reduction strategy simulated with the model results in compliance with the final nitrogen target. Staff believes that this result is a function of model limitations and the state of understanding of macrophyte dynamics (see "b", above). The proposed Implementation Plan includes requirements for further monitoring and model update so that reasonable and appropriate nitrogen reduction strategies can be identified.

Staff recommends that the 80% reduction in phosphate sediment flux assumed in model run 20b, together with a 25% reduction in macrophyte phosphorus and nitrogen loads (split evenly between phosphorus and nitrogen) be assumed in calculating the nutrient loading capacity for the proposed final numeric targets.

Table 5-1. WASP model scenarios and average nutrient concentrations for the four main lake TMDL stations for each model run

MODEL RUN	EXTERNAL LOAD REDUCTION	MACROPHYTE LOAD REDUCTION	P04-P SEDIMENT FLUX REDUCTION	AMMONIA SEDIMENT FLUX REDUCTION	TOTAL N (µg/L)	TOTAL P (µg/L)	CHLA[1] (µg/L)
Model Run 15q	Calibration	Calibration	Calibration	Calibration	1259	48	15
Model Run 16	50%	none	none	none	1259	48	15
Model Run 16b	100%	none	none	none	1259	48	15
Model Run 17	none	none	50%	none	2788	40	12
Model Run 17c	25%	none	50%	none	2788	40	12
Model Run 17d	50%	none	50%	none	2788	40	12
Model Run 18	none	none	50%	50%	1202	40	12
Model Run 19	none	none	75% for segment 10	75% for segment 10	1247	47	15
Model Run 20	none	50%	50%	none	3617	24	7
Model Run 20a	none	25%	60%	none	3802	30	8
Model Run 20b	none	50%	80%	none	5253	19	3
Model Run 20c	none	50%	80%	80%	2736	19	3
Model Run 20d	none	25%	70%	none	4329	29	7
Model Run 21	none	none	80% in segments 2 and 4	80% in segments 2 and 4	1252	42	13
Model Run 21b	none	50%	80% in segments 2 and 4	80% in segments 2 and 4	1599	26	9
Model Run 21c	50%	50%	80% in segments 2 and 4	80% in segments 2 and 4	1600	26	9
Model Run 22	none	none	80% in segments 8 and 10	80% in segments 8 and 10	1201	45	14
Model Run 22b	none	50%	80% in segments 8 and 10	80% in segments 8 and 10	1444	29	11
Model Run 22c	50%	50%	80% in segments 8 and 10	80% in segments 8 and 10	1445	29	11
Model Run 23	none	25%	50%	50%	1684	32	10
Model Run 24	none	10%	60%	none	3510	35	10
Model Run 25	none	50%	none	none	1167	32	13
Model Run 25a	none	25%	none	none	1199	40	14
Model Run 26a	none	25%	70%	70% in segments 8&10; 40% in segments 2&4	3301	29	7
Numeric Targets (Interim)						**35**	**10**
Numeric Targets (Final)					**1000**	**20**	**5**

[1]Chla averages are growing season averages (May 1-Oct. 31); TP, TN and Chla concentrations were summarized from the model output using the years 2001-2003.



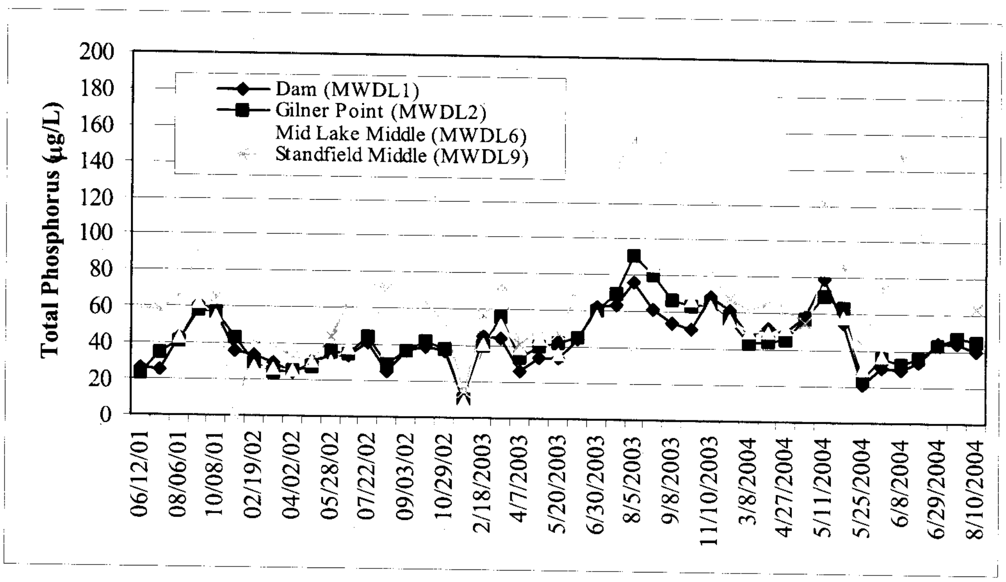


Figure 5-4 a) Total nitrogen and b) Total phosphorus photic zone water column concentrations from 2001-2004.

Note: 1st Sonar application was initiated on May 13, 2002 and concluded on June 12, 2002.
2nd Sonar application was initiated on June 5, 2003 and concluded on July 9, 2003.
Trial alum application (Papoose Bay only) was initiated and concluded on October 22, 2003
Lakewide alum application was initiated on May 24, 2004 and concluded on June 19, 2004.

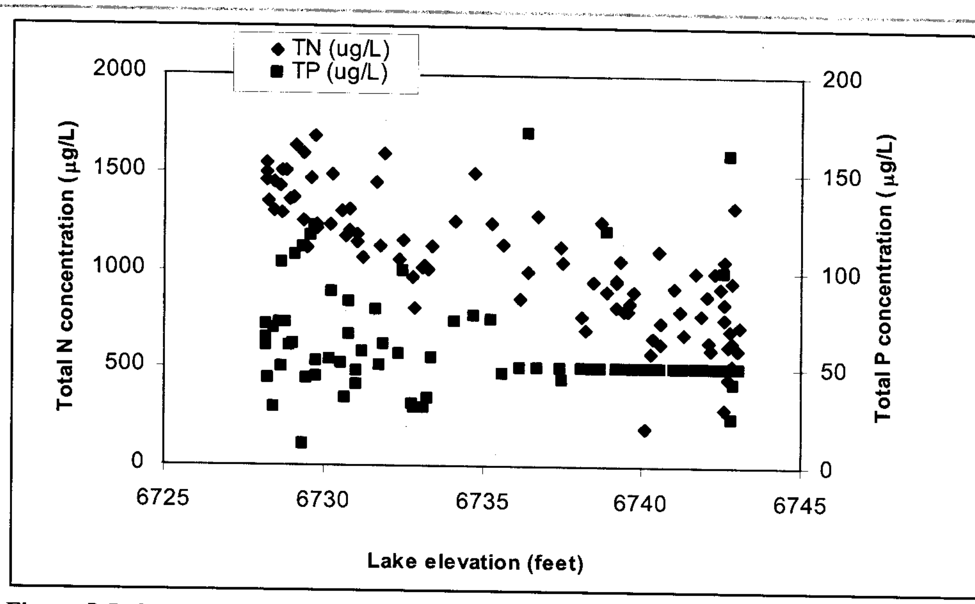


Figure 5-5. Total N and Total P concentrations as a function of lake elevation

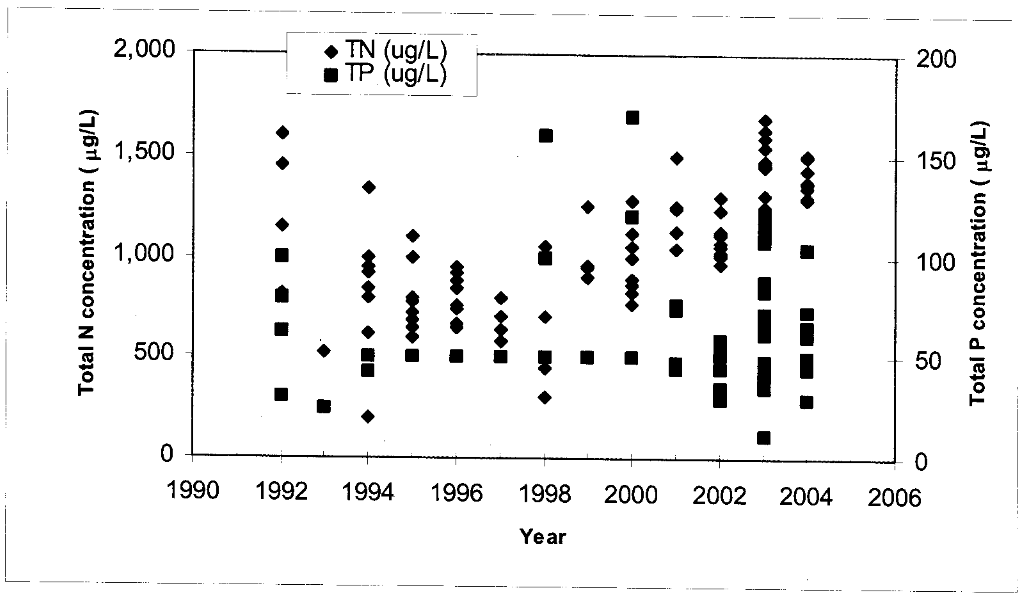


Figure 5-6. Total N and Total P concentrations as a function of year

Note: 1st Sonar application was initiated on May 13, 2002 and concluded on June 12, 2002.
2nd Sonar application was initiated on June 5, 2003 and concluded on July 9, 2003.
Trial alum application (Papoose Bay only) was initiated and concluded on October 22, 2003
Lakewide alum application was initiated on May 24, 2004 and concluded on June 19, 2004

5.2 Proposed TMDLs

Tables 5-2 and 5-3 summarize the proposed phosphorus and nitrogen TMDLs for Big Bear Lake under dry conditions, defined by the conditions observed from 1999-2003. During this period, the precipitation ranged from 0-23 inches, inflow ranged from 0-3049 AF and lake levels ranged from 6671 –6735 feet. The TMDLs include the allowable loads from all external sources and those from internal lake sediments and macrophytes, expressed in terms of annual averages for calendar years (January 1- December 31) that meet the dry condition definition as expressed above.

These TMDLs are based on the conclusions drawn in the preceding section regarding the effects and feasibility of loading reduction scenarios simulated by the WASP model. The TMDLs, as well as the WLAs and LAs (Section 6.0) are based on the average of simulated nutrient loads from the 5-year period, 1999-2003. Estimated existing nutrient loads are also based on the average of nutrient loads from this 5-year period (Table 4-5).

As discussed in the preceding section, the proposed TMDLs are projected to assure compliance with the recommended interim and final numeric targets identified in Section 3.1, with the exception of the final numeric target for nitrogen. Again, staff believes that the apparent failure to achieve the final nitrogen numeric target reflects model limitations and data gaps, both of which are to be addressed as part of the implementation of these TMDLs (see Section 10). This will entail data collection, model refinement and, likely, refinement of the TMDLs.

Table 5-2. Nutrient TMDL to achieve the interim target of phosphorus (35 μg/L) for Big Bear Lake during dry conditions (to be met as soon as possible, but no later than 2010) represented as annual averages for dry calendar years (January 1 – December 31) (all numbers in lbs/yr)

	TP load	Existing TP load
Internal loading	24,255*	39,331
External loading	1757	1757
TMDL	**26,012**	**41,088**

*Assumes a 60% reduction in internal phosphorus sediment loading and a 12.5% reduction in macrophyte TP loads

Table 5-3. Nutrient TMDLs to achieve the final targets of phosphorus (20 μg/L) and nitrogen (1000 μg/L) for Big Bear Lake for dry conditions (to be met as soon as possible, but no later than 2015) represented as annual averages for dry calendar years (January 1 – December 31) (all numbers in lbs/yr)

	TP load	**Existing TP load**	**TN load**	**Existing TN load**
Internal loading	19,978*	39,331	254,710⁺	269,328
External loading	1757	1757	26,190	26,190
TMDL	**21,735**	**41,088**	**280,900**	**295,518**

*Assumes an 80% reduction in internal phosphorus sediment loading and a 12.5% reduction in macrophyte TP loads

⁺Assumes a 12.5% reduction in macrophyte TN loads

The next section describes the allocation of these proposed TMDLs to different sources.

6.0 TMDL ALLOCATIONS

As discussed in Section 4.0, nutrient loads to Big Bear Lake come from both point source and nonpoint source discharges. The TMDLs must account for both types of inputs, as well as a margin of safety. This is expressed as follows:

TMDL = ΣWLA + ΣLA + MOS

where:

WLA = wasteload allocations for point source discharges
LA= load allocations for nonpoint source discharges, and
MOS=Margin of Safety

The Margin of Safety is incorporated in the proposed Big Bear Lake nutrient TMDLs via conservative assumptions. No explicit numeric MOS is included (see Section 8.0).

In order to derive the proposed waste load allocations (WLAs) for point source discharges and load allocations (LAs) for nonpoint source discharges, staff utilized the HSPF model results from Hydmet, Inc. (2004), the WASP model results from Tetra Tech (2004a), in-lake sediment release studies from Anderson and Dyal (2003) and Anderson et al. (2004) and macrophyte studies from ReMetrix (2004) to determine current nitrogen and phosphorus loading. The allowable loads defined by the TMDLs (Tables 5-2 and 5-3) were allocated among the sources, and the reduction required from each of the sources was then determined. Like the TMDLs, the proposed WLAs and LAs apply to dry water years only and are expressed as annual averages (see Section 5.2). As previously indicated, the proposed implementation plan will require the responsible parties to monitor the wet and average hydrological events to calibrate the model and develop TMDLs/allocations that address all hydrological conditions.

Point source discharges of nutrients to Big Bear Lake include urban storm and non-stormwater runoff (MS4 and Caltrans). The recommended wasteload allocations for this source do not include any assumptions to account for future growth because the watershed is close to its build-out capacity.

Nonpoint source discharges of nutrients considered in the HSPF simulation include forest and resort runoff. Nonpoint and point source discharges of nutrients considered in the WASP simulation for Big Bear Lake include those from atmospheric deposition, HSPF simulation including forest, resort and urban runoff and internal loading from sediments and macrophytes. Although resuspension and settling processes occur in Big Bear Lake, and settling loads could be calculated from the WASP model output, these two processes were not used to calculate the internal loading amount from sediment. No data have been collected for these two processes, both of which are very dynamic. Therefore, staff believes that using only the actual measured sediment flux rates to calculate nutrient loads from sediment is a reasonable approach for the Big Bear Lake nutrient TMDLs.

The proposed wasteload and load allocations can be expressed as follows:

ΣWLA = Urban (MS4) WLA

ΣLA = forest LA + resort LA + internal sediment LA + atmospheric deposition LA + internal macrophyte LA

Accordingly, the proposed nutrient TMDLs are expressed as:

TMDL = MS4 WLA + forest LA + resort LA + int. sediment LA + atmos LA + int. macrophyte LA

Again, no explicit MOS is incorporated in the proposed TMDLs.

Proposed WLAs and LAs to achieve the interim phosphorus target and final phosphorus and nitrogen targets for all sources for Big Bear Lake for dry hydrological conditions are shown in Tables 6-1 and 6-2, respectively. The following discussion describes the derivation of the LAs and WLAs.

Table 6-1. Proposed interim TMDL, wasteload and load allocations for Big Bear Lake during dry conditions (to be achieved as soon as possible, but no later than 2010)*

		TP load allocation (lbs/yr)	Existing TP load (lbs/yr)	Reduction (%)
TMDL		**26012**	**41088**	**37**
WLA		**475**	**475**	**0**
	Urban	475	475	**0**
LA		**25537**	**40613**	**37**
	Internal sediment source	8555	21388	**60**
	Internal macrophyte source	15700	17943	**12.5**
	Atmospheric deposition	1074	1074	**0**
	Forest	175	175	**0**
	Resort	33	33	**0**
MOS		**0**		

*Specified as an annual average based on a calendar year (January 1-December 31) for dry hydrological conditions only.

Table 6-2. Proposed final TMDLs, wasteload and load allocations for Big Bear Lake during dry conditions (to be achieved as soon as possible, but no later than 2015)*

		TP load allocation (lbs/yr)	Existing TP load (lbs/yr)	Reduction (%)	TN load allocation (lbs/yr)	Existing TN load (lbs/yr)	Reduction (%)
TMDL		**21735**	**41088**	**47**	**280900**	**295518**	**5%**
WLA		**475**	**475**	**0**	**3445**	**3445**	**0**
	Urban	475	475	0	3445	3445	0
LA		**21260**	**40613**	**48**	**277455**	**292073**	**5%**
	Internal sediment source	4278	21388	80	152386	152386	0
	Internal macrophyte source	15700	17943	12.5	102324	116942	12.5%
	Atmospheric deposition	1074	1074	0	21474	21474	0
	Forest	175	175	0	460	460	0
	Resort	33	33	0	811	811	0
MOS		**0**			**0**		

*Specified as an annual average based on a calendar year (January 1-December 31) for dry hydrological conditions only.

Atmospheric Deposition

The proposed load allocation for atmospheric deposition for Big Bear Lake is the same as the estimated existing load discussed in Section 4.2 (TN = 21,474 lbs/yr, TP = 1,074 lbs/yr). Based on this value, atmospheric loading contributes 7% of the nitrogen load and nearly 3% of the phosphorus load to Big Bear Lake. Studies to be conducted in the watershed should allow refinement of the allocation based on watershed-specific data. Future reduction of this source is contingent on implementation of relevant air quality management plans by the Southern California Air Quality Management District (SCAQMD) and/or the California Air Resources Board (CARB).

Internal Nutrient Loads from Sediment

To determine the internal sediment loading allocation for Big Bear Lake, staff assumed that the alum project, in conjunction with the planned east end dredge project, will reduce phosphorus loads by 60% in order to meet the proposed interim total phosphorus TMDL and interim numeric target of 35 μg/L (see discussion in Section 5.1). An 80% reduction in internal phosphorus loading rate is assumed in order to meet the final numeric phosphorus TMDL and target (20 μg/L). Because the restoration projects have the potential to reduce phosphorus loads more than nitrogen loads, no reduction of sediment nitrogen loads was assumed for the purposes of the load allocation.

Internal Nutrient Loads from Macrophytes

To determine the internal macrophyte loading allocations for Big Bear Lake, staff assumed a 25% reduction, split evenly between total nitrogen and total phosphorus, to meet both the interim and final TMDLs. As shown in Tables 6-1 and 6-2, the proposed LAs for macrophyte loads are 15,700 lbs/yr of phosphorus (interim and final) and 102,324 lbs/yr of nitrogen (final[51]), respectively. Note that these loads are still greater than those loads calculated previously for the Big Bear Lake nutrient budget report (Section 5.1). For this reason, even though a 50% reduction in macrophyte loads was required to meet the proposed final phosphorus numeric target, staff believes that only a 25% reduction in macrophyte loads is appropriate (see Section 5.1, Conclusions).

Urban Storm and Non-stormwater runoff, forest and resort

The remaining existing or potential nutrient sources (i.e., urban runoff, runoff from forest and resort land uses) originate from the various land use practices in the watershed. Because there is no reduction required for any of the external HSPF simulated nutrient loads to meet the proposed dry condition TMDLs, the proposed WLAs are the same as the existing urban loads and the proposed LAs for forest and resort discharges are the same as the existing loads.

As stated above, the TMDL allocations proposed in Tables 6-1 and 6-2 apply as annual averages during dry hydrological conditions only, which means that the average loads from each source over a calendar year that is characterized as dry (see Section 5.2) shall not exceed the allocations specified in Tables 6-1 and 6-2. The proposed allocations to meet the interim TP TMDL under dry conditions are proposed to be achieved as soon as possible, but no later than 2010. The proposed allocations to meet the final TP and TN TMDLs under dry conditions are to be achieved as soon as possible, but no later than 2015.

The proposed implementation plan includes requirements for the responsible parties to collect additional data to enable the calibration of the models for wet and average hydrological periods (see Section 10). As previously indicated, TMDLs, WLA and LAs for wet and/or average hydrological conditions will be proposed once additional data have been collected.

[51] As described in Section 3.1.1., only a final total nitrogen target is proposed.

7.0 SEASONAL VARIATION AND CRITICAL CONDITIONS

TMDLs must include consideration of seasonal factors and critical conditions. Consideration of seasonal variations in nutrient TMDLs is necessary to account for variations in the rates of nutrient input and internal cycling in aquatic ecosystems that occur naturally and, in some cases, as the result of human activities. In Big Bear Lake, external loading of nutrients is greatest during the winter and spring months, when there is higher precipitation and snow melt runoff. As spring arrives, macrophytes start to grow using nutrients sorbed to the lake sediments and present in the water column. As summer progresses, higher temperatures and increased production of algae and/or macrophytes can lead to decreases in dissolved oxygen concentration. If anoxic conditions develop, nutrient releases from the sediment will increase, spurring more algal growth. Soluble phosphorus and nitrogen release from the sediments is greatest during the summer due to increased temperatures and lower dissolved oxygen concentrations (Anderson and Dyal, 2003). As fall arrives and water temperatures decline, macrophytes die-off and decay and nutrients are released back into the water column or are taken up by attached algae. This process can in turn cause a short burst of algae growth. Decaying plant matter is deposited on the lake bottom and mineralized.

Consideration of the critical conditions in a body of water ensures that even under the worst water quality conditions, water quality standards will be met through the implementation of the TMDLs. The most critical condition for attainment of aquatic life and recreational uses in Big Bear Lake occurs during summer, when the greatest release of phosphorus and nitrogen from the sediment occurs and when it is typically dry, with little inflow and decreased lake levels, causing increases in nutrient concentrations. During dry periods, internal loads from the sediment and macrophytes are the most important sources of nutrients driving the eutrophication process. Macrophyte biomass is also at its peak during late summer/early fall. Both macrophyte growth and algae can deplete oxygen, leading to stresses on aquatic life and increasing the rate of nutrient release from the sediment. The summer period is also the peak period for recreational activities in the lake.

The nutrient TMDLs for Big Bear Lake account for seasonal and annual variations in external and internal phosphorus loading, as well as critical conditions, in the following ways:

1) The proposed TMDLs address the critical dry conditions by focusing on the control of the internal sediment loads that dominate during these periods. Attainment of the TMDLs requires removal or inactivation of sediment phosphorus. Reductions in internal phosphorus and nitrogen loads will reduce the risk of oxygen depletion in the hypolimnion. Preventing oxygen depletion, and enhancing oxygenation with in-lake aerators will also reduce phosphorus release. The proposed TMDLs addresses the critical conditions by requiring that total phosphorus loads from sediment be reduced by 60% and total phosphorus and total nitrogen loads from macrophytes be reduced each by 12.5% to meet the proposed interim phosphorus TMDL. To meet the proposed final total phosphorus and total nitrogen TMDLs, total phosphorus loads from sediment must be reduced by 80% and total phosphorus and total nitrogen loads from macrophytes must be reduced by 12.5% each.

2) The proposed TMDLs recognize that different nutrient inflow and cycling processes dominate the lake during different seasons. These processes are simulated in the WASP model (though, as already noted (Section 5.1), they are not all simulated dynamically), using data from a multi-year period. As discussed previously (Section 5.1), the WASP model used data collected from 2001-2003 and extrapolated to 1999 and 2000. Nutrient flux rates were obtained during both summer and fall in 2002 and 2003 as well as winter in 2003 (Anderson and Dyal, 2003; Anderson et al., 2004). Tetra Tech (2004a) incorporated these different flux rates into the time functions that represent the fluxes as a function of either time of year or depth. Similarly, the macrophyte loads

incorporated the growing cycle to estimate the peak biomass and also used the growing season average depths from 1999-2003 to determine total biovolume of macrophytes in each segment (Tetra Tech, 2004a). Thus, the results of the WASP model are a reflection of all of the seasonal processes. Although it would be preferable to include a longer period of record that includes wet and average years and to develop TMDLs that take these annual variations in hydrologic conditions into account, this was not possible because the data were not available. This is addressed in the proposed implementation plan.

3) The proposed implementation plan (Section 10) includes requirements for additional data collection and analyses designed to better understand nutrient dynamics in the lake under varying hydrologic conditions, which should allow for refinement of the lake model and revisions of the TMDLs, where appropriate.

8.0 MARGIN OF SAFETY

TMDLs must include an explicit or implicit margin of safety (MOS) to account for uncertainty in determining the relationship between pollutant loads and impacts on water quality. An explicit MOS can be provided by reserving (not allocating) part of the TMDL and therefore requiring greater load reductions from existing and/or future sources. An implicit MOS can be provided by conservative assumptions in the TMDL analysis. The assumptions that account for the MOS must be adequately identified.

Sources of uncertainty in the Big Bear Lake nutrient TMDL development analysis include: 1) the lack of watershed specific data on total phosphorus and total nitrogen loading from surface runoff to allow calibration of the water quality component of the watershed model; 2) the lack of discharge measurements from the tributaries; 3) the inherent seasonal and annual variability in delivery of total phosphorus and total nitrogen from external sources, and in nutrient cycling within Big Bear Lake; 4) assumptions made about the rate of nutrient release from the sediment and the efficiency of potential lake treatment technologies; 5) assumptions made about the contribution of nutrient loads from macrophytes and the inherent annual variability in delivery of total phosphorus and total nitrogen from macrophyte die-off and decay; 6) the absence of a high elevation weather station to obtain data needed to calibrate the watershed model; 7) assumptions made about the estimated biomass of macrophytes and the percentage of nutrients that are recycled to the water column and to the sediments; 8) assumptions made about the contribution of total nitrogen and total phosphorus from atmospheric loads; 9) the lack of established relationships between in-lake total nitrogen and total phosphorus concentrations and either algae growth or macrophyte coverage; 10) the inability of the WASP model to model macrophyte nutrient dynamics, likely leading to total nitrogen predictions that do not achieve the proposed final target; and 11) the lack of measured sedimentation and resuspension rates. In addition, the lake and tributary water column monitoring and the sediment and macrophyte studies were carried out during dry years; therefore, the WASP model can only be used to predict water quality during dry hydrological conditions.

To address these uncertainties, conservative approaches were applied in setting the numeric targets, TMDLs, WLAs, and LAs. Staff selected the proposed interim total phosphorus numeric target conservatively by using the 25th percentile of data collected before the application of the aquatic herbicide Sonar (see Section 3.1.1). The data used were collected at different times of the year, not only during summer, when phosphorus concentrations are higher. The numeric targets are also proposed as annual averages. The intent is to set targets that will, when achieved, result in improvement of the trophic status of Big Bear Lake year-round. Again, staff is well aware of the need to obtain data necessary to support development of model capability and TMDLs that address wet and average hydrologic conditions, as well as dry conditions. The WASP model setup also included conservative assumptions, such as estimating a higher macrophyte density than what had been calculated previously. These approaches therefore address the MOS implicitly. As new data are collected under various hydrologic conditions, data gaps will be filled, an uncertainty analysis can be conducted and the MOS and TMDLs can be adjusted as appropriate.

9.0 IMPLEMENTATION PLAN

Federal regulations require the State to identify measures needed to implement TMDLs in the state water quality management plan (Basin Plan) (40 CFR 130.6). California law requires that Basin Plans have a program of implementation to achieve water quality objectives (Water Code Section 13242). The implementation program must include a description of actions necessary to achieve the objectives, a time schedule for these actions, and a description of the surveillance and monitoring activities to determine compliance with the objectives. TMDLs are not water quality standards and do not establish new water quality objectives; rather, they are a mechanism to attain existing standards, including narrative and numeric objectives. An implementation plan ensures that the TMDL achieves this purpose.

Staff proposes that the Big Bear Lake nutrient TMDLs be adopted as phased TMDLs. The phased implementation framework provides time to conduct further monitoring and assessment, including refining the existing watershed and in-lake models. The results of these studies are expected to provide the analytical basis for modifying the TMDLs, WLAs, LAs and/or other elements of the TMDLs.

The proposed Basin Plan amendment, shown in Attachment A, includes an implementation plan and monitoring program designed to implement the TMDLs and evaluate their effectiveness. Implementation is expected to result in compliance with the proposed nutrient TMDLs and allocations for Big Bear Lake and thereby ensure protection of the beneficial uses of this body of water. The proposed implementation plan includes requirements directed at both point and nonpoint sources. Implementation of the Big Bear Lake nutrient TMDLs is the responsibility of the dischargers of nutrients, including the U.S. Forest Service, Big Bear Mountain Resorts, the City of Big Bear Lake, Caltrans, County of San Bernardino, and the San Bernardino County Flood Control District. The Big Bear Municipal Water District is committed to be a cooperating partner, working with the stakeholders to implement the Big Bear Lake nutrient TMDLs.

Given the lack of data on beneficial use impacts to Rathbun, Grout, and Summit Creeks from nutrients, the proposed TMDL implementation plan includes a requirement to investigate these creeks.

Regional Board staff plan to coordinate implementation with the following agencies, programs and policies:

- The Regional Board's Watershed Management Initiative (WMI) program for the Big Bear Lake watershed
- The Regional Board's permitting and enforcement sections
- The Regional Board's stormwater section
- The State Board's Nonpoint Source (NPS) Implementation and Enforcement Policy
- The Big Bear Lake TMDL Workgroup coordinated by the Big Bear Municipal Water District (BBMWD)
- The U.S. Forest Service, San Bernardino National Forest (Big Bear Lake Ranger Station) and the existing (Management Agency Agreement) MAA between the SWRCB and the Forest Service regarding control of nonpoint source pollution from forest activities within California
- The U.S. Army Corps of Engineers and the Corps' Feasibility Study within the Big Bear Lake watershed
- The U.S. Fish and Wildlife Service, and
- The California Department of Fish and Game

9.1 Implementation Actions by the Regional Board

In order to implement the TMDLs, WLAs and LAs, Board staff proposes that the Regional Board undertake the following actions. Proposed dates for implementation of these actions are specified in the proposed Basin Plan amendment (Attachment A).

1. Establish New Waste Discharge Requirements/Conditional Waivers
   a) The Regional Board will work with the responsible parties and the Big Bear Municipal Water District to issue a general NPDES permit for restoration activities (e.g., alum or herbicide) planned for Big Bear Lake. A requisite provision of that permit would be aquatic plant monitoring.

   b) Review the State Board's new NPS policy and act accordingly with respect to nonpoint sources. This could include drafting new WDRs/conditional waivers for the Big Bear Mountain Resorts and ensuring that the MAA and its provisions between the USFS and SWRCB are being met through the issuance of new WDRs/conditional waivers.

2. Revise Existing Waste Discharge Requirements
   The Regional Board shall review and revise, as necessary, the following existing NPDES permit to incorporate the appropriate WLAs, compliance schedules and monitoring program requirements.
   Waste Discharge Requirements for the San Bernardino County Flood Control District, the County of San Bernardino and the City of Big Bear Lake, Areawide Urban Runoff, NPDES No. CAS 618036 (Regional Board Order No. R8-2002-0012)

3. Review/Revise Site-Specific Water Quality Objectives for Big Bear Lake
   The Regional Board shall review, and revise as necessary, the numeric water quality objectives for total phosphorus and total inorganic nitrogen for Big Bear Lake. The Regional Board shall examine the appropriateness of establishing numeric water quality objectives for total nitrogen for Big Bear Lake. Finally, the Regional Board shall consider whether it would be appropriate to develop numeric or narrative objectives based on the response variables identified in Section 3 of this report (chlorophyll *a*, macrophyte coverage and percentage of nuisance aquatic vascular plant species). It may be appropriate to consider such objectives in lieu of numeric objectives for phosphorus and/or nitrogen.

4. Review collected data on beneficial use impairment from nutrients in Rathbun Creek, Summit Creek, and Grout Creek and assess whether TMDLs need to be developed or if these creeks should be recommended for delisting from the 303(d) list of impaired waters.

5. Utilize new monitoring data and model simulations to establish load and wasteload allocations for wet and average hydrological periods and/or to revise the dry weather nutrient TMDLs.

6. Conduct Atmospheric deposition studies
   During the watershed modeling, literature searches suggested that atmospheric deposition could be a significant source of the total nutrient load in the overall nutrient budget of Big Bear Lake. Atmospheric deposition of nitrogen and phosphorus will be quantified through analysis of rainwater and dryfall samples in the Big Bear Lake watershed. Coordination with the SCAQMD and CARB will be encouraged to determine any effective means of reducing nutrient loads from atmospheric deposition.

9.2 Implementation Actions by Other Agencies/Entities

The first phase of these dry condition TMDLs does not require that steps be taken to reduce external nutrient loading, which occurs principally during wet years. However, it is recognized that external inputs remain in the lake for an extended period and contribute significantly to internal sediment loading and macrophyte growth, which are addressed by these TMDLs. Accordingly, the proposed implementation plan includes requirements for external nutrient dischargers to participate in the development of internal sediment loading control measures and macrophyte reduction/aquatic plant management programs. The parties are required to continue to conduct watershed and in-lake monitoring, which will be used to refine the dry condition TMDLs and to develop TMDLs for wet and average hydrologic conditions. The parties are also required to participate in programs designed to refine the watershed and in-lake nutrient models and to develop a multimetric index for Big Bear Lake. Each of these tasks is described in the proposed Basin Plan amendment (Attachment A). The monitoring related tasks are described in more detail in the next section (Section 10).

9.3 Implementation Schedule

Regional Board staff proposes that the interim target for Big Bear Lake (see Section 3, Table 3-1) and the allocations specified in Table 6-1 be met as soon as possible but no later than 2010. Staff recommends that the final targets for Big Bear Lake (see Section 3, Table 3-1) and allocations (Table 6-2) be met as soon as possible but no later than 2015.

10.0 MONITORING PROGRAM RECOMMENDATIONS

Section 13242 of the California Water Code specifies that Basin Plan implementation plans must contain a description of the monitoring and surveillance programs to be undertaken to determine compliance with water quality objectives. As part of the incorporation of the proposed Big Bear Lake nutrient TMDLs into the Basin Plan, specific monitoring requirements are proposed in order to evaluate the effectiveness of actions and programs implemented pursuant to the TMDL. These requirements are described below and specified in the proposed Amendment (Attachment A). Since the Big Bear Lake TMDLs are proposed as phased TMDLs, follow-up monitoring and evaluation is essential to validate and revise the TMDLs as necessary and to develop wet and/or average TMDLs, WLAs and LAs.

10.1 Big Bear Lake In-lake Monitoring Program

The Big Bear Municipal Water District and various stakeholders in the watershed, along with Regional Board staff, implemented a Big Bear Lake in-lake monitoring program in 2001. This program, which is currently on-going, consists of the collection of water quality data along with depth profile measurements at stations in Big Bear Lake on a year-round basis. The purpose of this program is to evaluate changes in lake water quality due to nutrient input or other environmental factors. This monitoring program has been funded by stakeholders as well as by various grant programs.

Staff recommends that the proposed Basin Plan amendment include the requirement that the responsible parties continue the in-lake monitoring program to assess the response of the lake to the nutrient loadings and to determine if the load reductions result in the achievement of numeric targets (as proposed in Section 3.0).

10.2 Watershed-wide Nutrient Water Quality Monitoring Program

A watershed-wide nutrient monitoring program was implemented in 2001 by the Big Bear Municipal Water District and various stakeholders in the watershed along with Regional Board staff and is currently on-going. The purpose of this monitoring program has been to collect data needed to develop the nutrient TMDLs, as well as other TMDLs. The monitoring program consists of the collection of stream flow and water quality data in the Big Bear Lake watershed. Because there are no USGS stream gages in this watershed, this program is key to developing accurate loading estimates from the watershed and accurate inflow measurements. This watershed-wide monitoring program has been instrumental in the development of the proposed nutrient TMDLs and is critical to enable development of wet and/or average TMDLs, WLAs and LAs and the implementation plan.

The proposed Basin Plan amendment specifies that the responsible parties shall continue to implement this watershed-wide nutrient monitoring program and focus on collecting nutrient data from specific nutrient sources (e.g., open space/forest lands, urban runoff, and the ski resorts). The locally-built weirs and ISCO stormwater samplers that have been installed as part of the watershed-wide monitoring program, or other acceptable flow monitoring and sampling devices, must also be continually operated and maintained, and water quality samples need to be collected from all stations at the frequency identified in the Basin Plan Amendment (Attachment A) to quantify nutrient loads from various sources in the watershed. In addition, a high elevation weather station should be installed and maintained in order to obtain the necessary data for calibration of the present watershed model. The data generated will not only be used to evaluate TMDL compliance, but will also be used to calibrate/update the current watershed model.

10.3 Special studies

Finally, staff believes that there is a need to conduct special, nutrient-related studies in the watershed. These studies should be jointly undertaken by the responsible parties as identified in Section 9.0.

- In-lake treatment of sediment to remove nutrients: The applicability of various in-lake treatment technologies to prevent/reduce the release of nutrients from lake sediments needs to be evaluated in order to develop a long-term strategy for control of nutrients from the sediment. Examples of treatment technologies include aeration, alum treatment, wetland treatment, fishery management, and dredging. The BBMWD has already implemented many of these in-lake treatment technologies (e.g., alum treatment and aeration) and will conduct a pilot dredging study in 2005. The findings of these in-lake treatment technologies need to be summarized and strategies developed based on cost and effectiveness of reducing nutrient loads from in-lake sediments.

- Model update/development: Update/revision of the watershed nutrient model developed by Hydmet, Inc. (2004) will be needed in the future as additional data are generated. An updated watershed model could be used to determine BMP effectiveness and to determine TMDL, WLA and LA compliance. The model could also be used as a tool to evaluate potential pollutant trading options. Update/revision of the in-lake model will also be needed in the future as additional data are generated. A new in-lake model may be developed to more accurately simulate macrophyte and sediment processes. An updated in-lake model or new in-lake model will be used for developing wet and/or average TMDLs, WLAs and LAs, as well as future refinement of the proposed dry TMDLs, WLAs, LAs and numeric targets.

- Aquatic Plant Management Plan: Development and implementation of an Aquatic Plant Management Plan by the responsible parties identified in Section 9.0 to address strategies for aquatic plant control, monitoring aquatic vegetation and tracking changes in macrophyte habitat through vegetation assessments and GIS mapping, and effectiveness of prior treatment strategies.

- Multimetric Index: Development of a multimetric index for Big Bear Lake by the responsible parties identified in Section 9.0. The index will incorporate biological, chemical and physical parameters. This index will incorporate sampling to calculate trophic state, aquatic macrophyte biomass and species, fish assemblages, shore zone habitat, phytoplankton, and zooplankton for effective assessment of improvement in overall lake health.

11.0 ECONOMIC CONSIDERATIONS

Regional Water Boards are required to adopt TMDLs as basin plan amendments. There are three statutory triggers for consideration of economics in basin planning. These triggers are:

- Adoption of an agricultural water quality control program (Water Code Section 13141). The Regional Board must estimate costs and identify potential financing sources in the Basin Plan before implementing any agricultural water quality control plan.
- Adoption of water quality objectives (Water Code Section 13241). The Regional Board is required to consider a number of factors, including economics, when establishing or revising water quality objectives in the Basin Plan.
- Adoption of a treatment requirement or performance standard. The Regional Board must comply with the California Environmental Quality Act (CEQA) when amending the Basin Plan. CEQA requires that the Board consider the environmental effects of reasonably foreseeable methods of compliance with Basin Plan amendments that establish performance standards or treatment requirements, such as TMDLs. The costs of the methods of compliance must be considered in this analysis.

It should be noted that in each of these three cases, there is no statutory requirement for a formal cost-benefit analysis.

There are no agricultural operations in this watershed, therefore the first statutory trigger does not apply. The adoption of this TMDL does not constitute the adoption of new or revised water quality objectives, so the second statutory trigger also does not apply here[52]. The proposed TMDLs do not require the implementation of external load control measures. However, the proposed implementation plan requires the stakeholders to take steps to reduce internal sediment and macrophyte nutrient loading, and to participate in monitoring and other efforts designed to assess compliance with and refine the TMDLs, and to develop TMDLs for wet and average hydrologic conditions. The costs to be considered are those associated with these actions.

The proposed implementation plan requires continuation of the on-going watershed and lake monitoring to assess the effectiveness of lake improvement strategies and to determine compliance with the TMDL numeric targets. Studies identified in Section 10 are also required as part of the TMDL implementation plan. Most of the studies are funded under two Prop. 13 Phase III grants awarded to the Big Bear Municipal Water District and the East Valley Resource Conservation District. These studies are scheduled to begin in 2005 and 2006. In addition, funding for monitoring programs will be covered through 2006 under these grants. Table 11-1 shows some of the costs of the ongoing monitoring.

[52] As discussed in Section 3.1, it appears that the numeric objectives established in the Basin Plan for total phosphorus and total inorganic nitrogen in Big Bear Lake are not protective and need to be revised. The numeric targets, and thus the TMDLs, WLAs and LAs, are not based on these objectives. Rather, they are based on best professional judgment of the levels necessary to comply with the narrative objectives established in the Basin Plan (Section 2.1).

Table 11-1. Cost estimates for nutrient TMDL monitoring

Medium	Study type	Cost per sample $
Sediment	Core flux	278
Sediment	Sediment traps	3000
Water	Composite -photic	175
Water	Discrete -bottom	95
Water	Phytoplankton	120
Water	Zooplankton	120
Water	Tributaries	140
Plant tissue	Biomass, aquatic plant species identification	112
Water	Hydroacoustic transect	275
Plant tissue	Biomass by scuba diving	511

Table 11-2 shows the costs associated with certain types of restoration activities.

By the end of 2007, the amount of money spent in the Big Bear Lake watershed for developing and implementing the Big Bear Lake TMDLs will have amounted to well over $4 million (Table 11-3). This amount includes grants funded by Proposition 13, Section 319(h) of the Clean Water Act and TMDL funds provided by the State. The USEPA also provided $50,000 for the WASP model effort. Not taken into consideration are the TMDL Task force budget of $90,000 per year, other funds contributed by the BBMWD, the $100,000 the U.S. Army Corps of Engineers spent on a reconnaissance study, or the money now being spent as part of the Corps' feasibility study.

Phase II of the Big Bear Lake Nutrient TMDLs is likely to address nutrient discharges from the various land uses in the watershed (urban, resort and forest) during average and wet conditions. Obviously, there are likely to be costs associated with any required reductions identified in Phase II. At that time, those economic impacts would be evaluated.

Table 11-2. Estimated costs of lake management options for Big Bear Lake

LAKE MANAGEMENT TECHNIQUE	TREATMENT ASSUMPTIONS	COST RANGE PER ACRE TREATED ($)
Sediment Nutrient Flux Control		
Aeration	Full or partial lift, prevention of anoxia	800 to 2,000
	Full or partial lift, DO> 5 mg/L	1,000 to 3,000
	Layer aeration, prevention of anoxia within layer	500 to 1,000
	Layer aeration, DO> 5 mg/L	700 to 1,200
Dredging	Average sediment depth = 2ft	15,000 to 50,000
	Average sediment depth = 5ft	25,000 to 80,000
Nutrient Activation	Alum with no buffering, external load controlled	500 to 700
Macrophyte Control		
Herbicide Treatment with Fluridone (SONAR)	Liquid formulation, single treatment	500 to 1,000
	Liquid formulation, triple treatment	1,000 to 2,000
	Pellet formulation	800 to 1,200
Harvesting	Moderately dense, submerged vegetation	200 to 600
	Very dense or difficult to cut/handle	1,000 to 1,500

Source: Table provided as a task deliverable for a Proposition 13 grant (Contract # 02-069-258-1 with the BBMWD) –reformatted by RWQCB staff

Table 11-3. Sources and amounts of funding for the Big Bear Lake Watershed

Funding Source	Project	Deliverables	Amount	Recipient
State TMDL funds	Nutrient monitoring	Watershed and lake nutrient monitoring from June 01-Oct.02	$40,000	BBMWD
State TMDL funds	Nutrient Budget	HSPF model WASP model Sediment core-flux analyses and sediment characterization Watershed and lake nutrient monitoring ISCO samplers Plant tissue analyses	$77,000	BBMWD
Prop. 13	Pilot-scale remediation	Lake wide fish survey Lake wide macroinvertebrate study Biological surveys (zooplankton, phytoplankton) Access database of all monitoring data Trial alum project in Papoose Bay Big Bear Lake Atlas website	$200,000	BBMWD
Federal 319(h) funds	Nutrient and plant remediation	Sonar application Pre-and post- treatment aquatic macrophyte surveys	$120,000	BBMWD
Prop. 13	High resolution aerial mapping	Low and high altitude aerial photography GIS coverages (DTM, contours, utility, parcels)	$490,000	SBC/City of Big Bear Lake
Prop. 13	Large-scale alum application	Lake wide alum application Water quality monitoring prior to, during and after project Sediment core-flux data	$500,000	BBMWD
Prop. 13	Lake and Tributary monitoring support	Continued water quality monitoring-2005 Phytoplankton and zooplankton analyses Preliminary macrophyte index	$80,000	BBMWD
Prop. 13	BMP implementation	BMP implementation in Snow Forest area NPS education	$250,208	EVRCD
Federal 106(g) funds	WASP model	WASP model Updated HSPF model runs	$50,000	RWQCB8
Prop. 13	Lake dredging and study	Continued water quality monitoring Studies needed for TMDL implementation High elevation weather station Monumented cross-sections Dredging of east end Update to Access database Model plan	$2,300,000	BBMWD

12.0 CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA)

The Secretary of Resources has certified the Basin Planning process as "functionally equivalent to" the preparation of an Environmental Impact Report (EIR) or a Negative Declaration pursuant to the California Environmental Quality Act (CEQA). However, in lieu of these documents, the Regional Board is required to prepare the following: the Basin Plan amendment; an Environmental Checklist that identifies potentially significant adverse environmental impacts of the Basin Plan amendment; and, a staff report that describes the proposed amendment, reasonable alternatives, and mitigation measures to minimize any significant adverse environmental impacts identified in the CEQA checklist. The Basin Plan amendment, Environmental Checklist, and staff report together are functionally equivalent to an EIR or Negative Declaration.

The draft Environmental Checklist (Attachment B to this report) concludes that there would be no potentially significant impacts on the environment caused by adoption of this Basin Plan amendment. Therefore, no mitigation measures are required.

This staff report will be followed by another report that includes comments received on the proposed amendment, staff responses to those comments, and a discussion of any changes made to the proposed amendment as the result of the comments or further deliberation by the Board, and/or Board staff. This follow-up report would address any additional CEQA considerations, including economics, that might arise as the result of any changes to the proposed amendment.

Consideration of Alternatives

1. No Project Alternative

The "No Project" alternative would be no action by the Regional Board to adopt TMDLs with implementation measures and a monitoring program. This alternative would not meet the purpose of the proposed action, which is to correct ongoing violations of the Basin Plan numerical objectives for TIN and total phosphorus, as well as narrative objectives regarding algae, and to prevent adverse impacts to beneficial uses. This alternative would result in continuing water quality standards violations and threats to public health and safety, and the local economy. This alternative would not comply with the requirements of the Clean Water Act.

2. Alternatives

The Regional Board could consider TMDLs based on alternative numeric targets, such as more restrictive numeric targets. However, the proposed numeric targets are based on the best scientific information now available concerning the eutrophic status of Big Bear Lake and factors contributing to that status. The proposed targets provide the best assurance that the narrative water quality objective for algal growth will be achieved and that the beneficial uses will be protected.

The Board could also consider an alternative TMDL implementation strategy that is based on a different compliance schedule approach. Adoption of a longer schedule would prolong non-attainment of the water quality standards. The proposed compliance schedule approach reflects the timing of implementation of projects for Big Bear Lake that are expected to result in improvements in lake water quality. The proposed compliance schedule also considers the need for additional studies to fill data gaps, particularly the collection of data during wet and average hydrological conditions, and address uncertainties in the TMDL calculation. The proposed compliance schedules are therefore considered reasonable.

3. Proposed Alternative

Staff believes that the recommended TMDLs reflect a reasoned and reasonable approach to the improvement of the beneficial uses of Big Bear Lake. The proposed implementation schedule also provides a realistic time frame in which to complete the tasks required by the TMDL.

13.0 PUBLIC PARTICIPATION

Federal TMDL regulations require public participation to give the public an opportunity to review and comment on the TMDLs. A number of opportunities for public participation are afforded throughout the entire TMDL Basin Plan Amendment process and through the CEQA review process.

- Basin Plan amendments require advanced public notice and a public hearing (CWC § 13244).
- CEQA requires circulation of a Notice of Filing to the public and interested public agencies.
- Public workshops are held by the Regional Board to consider evidence and testimony related to the proposed TMDL.
- Regional Board staff must prepare written responses to comments that are received at least 15 days before the Board's scheduled action (public hearing). For those late comments for which written responses are infeasible and for oral comments at the Board meeting, staff must respond orally at the Public Hearing.
- Draft TMDLs, Basin Plan Amendments, Public Notices, Notice of Filing, CEQA documentation are made available on the Regional Board's website.
- After Regional Board adoption of the Basin Plan Amendment, the SWRCB and the USEPA have their review and approval processes, which affords more opportunities for public participation.
- Documentation of all public participation, including copies of hearing notices, press releases, written public comments and written responses, and tapes or minutes of hearing testimony will be included in the administrative record of the Basin Plan amendments.

In June 2000, Regional Board staff convened a TMDL workgroup to assist staff in the development of the Big Bear Lake nutrient TMDLs. Soon thereafter, the Big Bear Municipal Water District hired Tim Moore of Risk Sciences as the TMDL facilitator. The BBMWD created the Big Bear Lake TMDL Task Force, which includes representatives from the Big Bear Municipal Water District, San Bernardino County Flood Control District, City of Big Bear Lake, the Big Bear Area Regional Wastewater Authority, Caltrans, Regional Board staff, Big Bear Mountain Resorts and recently, the USFS. The BBMWD also created a TMDL fund to pay for studies in the watershed. Contributors to date include the BBMWD, the City of Big Bear Lake, the San Bernardino County Flood Control District and the Big Bear Area Regional Wastewater Authority. The Big Bear Municipal Water District has been instrumental in assisting Regional Board staff in the development of the Nutrient TMDLs by compiling existing data, designing, coordinating and implementing the watershed and in-lake monitoring programs, and reviewing the results of studies conducted in the watershed. BBMWD has also secured a number of grant funds, including a Clean Water Act Section 319(h) grant that was used to reduce Eurasian watermilfoil, and several Proposition 13 funds (see Table 11-3). The Proposition 13 funds have funded a macroinvertebrate study, pilot and full-scale alum projects, lake and tributary monitoring, to name just a few items. In addition, the County of San Bernardino along with the City of Big Bear Lake was awarded a Proposition 13 grant to obtain aerial photos of the entire Big Bear Lake watershed for implementation of their stormwater program and for other projects within the watershed. The East Valley Resource Conservation District was also awarded a Proposition 13 grant to work with the USFS in reducing sediment and nutrient loads from an abandoned ski area in the watershed. Altogether, by the end of 2007, more than 4 million dollars will have been spent by the state and US EPA to develop and implement these TMDLs (Table 11-3).

14.0 STAFF RECOMMENDATION

Direct staff to prepare a Basin Plan amendment and related documentation to incorporate the TMDLs for nutrients for Big Bear Lake shown in Attachment A for consideration at a future public hearing.

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Appendix A – Summary of nutrient water quality for the 303(d) listed tributaries

Assessment of Existing Conditions Relative to Narrative Water Quality Objectives

This section describes conditions in the Big Bear Lake watershed that resulted in the inclusion of Rathbun Creek, Summit Creek, and Grout Creek as nutrient impaired on the 1994 303(d) list (Table A-1). Nutrient data that were evaluated and compared to the objectives for Rathbun Creek, Summit Creek, and Grout Creek as part of the initial TMDL problem identification were the data collected in 1994 by the Regional Board as a follow-up to the Clean Lakes Study (Table A-2), data collected from 1994-2000 by the BBMWD (Table A-3), tributary data collected by the Regional Board in 1998 (Table A-4), data collected by the SBCFCD as part of the stormwater sampling program from 1994-2000 (Table A-5) and data collected from 2001-2003 by the TMDL Task Force (Table A-6). For all datasets, tributary data are compared to Basin Plan Objectives specified in Section 2.1 of the TMDL document. For all creeks, no data exceed narrative water quality objectives for nitrate-N; unionized ammonia could not be calculated for the most part because temperature and pH were not taken simultaneously to the water quality sample. Dissolved oxygen was not recorded and chlorophyll *a* analyses were not conducted. Total nitrogen and TP concentrations are much higher for the tributaries when compared to Big Bear Lake water quality.

Total Phosphorus, TIN, Nitrate as N, Un-ionized ammonia. The nutrient-related data used to place Rathbun Creek, Summit Creek, and Grout Creek on the 1994 303(d) list were collected as part of a Clean Water Act Section 314 grant (Clean Lakes Study) titled, "Investigation of Toxics and Nutrients in Big Bear Lake." (Courtier and Smythe 1994). The data were collected between April 1992 and April 1993 (Table A-1).

Table A-1. Nutrient concentrations (µg/L) for the 303(d) listed creeks (April 1992-April 1993)

	Total P	Total N	TIN	NO3-N
Rathbun Creek at Fox Farm Rd.				
Average	65	1100	764	685
Median	65	1100	764	685
Number of samples	2	2	2	2
Number of non-detects	0	0	NP	0
Max	80	1400	1263	1170
Summit Creek at Swan Dr.				
Average	22	713	546	472
Median	20	400	315	260
Number of samples	3	3	3	3
Number of non-detects	1	0	NP	1
Max	40	1440	1223	1130
Grout Creek – North of Hwy 38				
Average	18	273	231	268
Median	20	200	85	268
Number of samples	3	3	3	2
Number of non-detects	1	0	NP	1
Max	30	520	532	510

NP = detection limit not provided

Data from 1994 were also used to assess the creeks for nutrients (Table A-2).

Table A-2. Nutrient concentrations (μg/L) for the 303(d) listed creeks (May 1994)

	Total P	Total N	TIN
Rathbun Creek at Fox Farm Rd.	30	1305	155
Number of samples	1	1	1
Summit Creek at Swan Dr.	50	965	585
Number of samples	1	1	1
Grout Creek – North of Hwy 38	10	1205	385
Number of samples	1	1	1

Data collected by the BBMWD from 1994-2000 were also evaluated (Table A-3).

Table A-3. Nutrient concentrations (μg/L) for the 303(d) listed creeks (BBMWD:1994-2000)

	Total P	Total N	TIN*	NO3-N**
Rathbun Creek				
Average	108	743	285	325
Median	50	600	200	200
Number of samples	23	23	23	23
Max	910	1500	1100	1100
Grout Creek				
Average	40	336	N/A	N/A
Median	25	350	N/A	N/A
Number of samples	14	14	14	14
Max	130	500	100	100

*TIN was calculated as the difference between TN and TKN (ammonia was below detection limits). Average and median TIN values for Grout Creek were all 0 μg/L.
Only one sample had a value above 0 μg/L.
**Only one Grout Creek sample had a value above the detection limit for nitrate-N.

Data collected by the Regional Board in 1998 at various sites in Rathbun Creek were also assessed for nutrients. As can be seen in Table A-4, the total phosphorus and TIN concentrations are high for all locations in the creek.

Table A-4. Nutrient concentrations (μg/L) for Rathbun Creek (1998)

	Total P	Total N	TIN	NO3-N
Rathbun Creek – Below Bear Mtn.				
Average	470	2110	1055	990
Number of samples	2	2	2	2
Max	590	2265	1545	1480
Rathbun Creek – Below Zoo				
Average	265	1785	1375	1310
Number of samples	2	2	2	2
Max	270	2305	2045	1980
Rathbun Creek – At Parking Lot				
Average	370	1030	770	705
Number of samples	2	2	2	2
Max	610	1315	1005	940
Rathbun Creek – At mouth				
Average	195	730	575	510
Number of samples	2	2	2	2
Max	260	795	585	520

Data collected by the SBCFCD as part of their NPDES monitoring program from 1994 to 2000 were also evaluated for nutrients (Table A-5).

Table A-5. Nutrient concentrations (μg/L) for Rathbun Creek (SBCFCD:1994-2000)

	Total P	Total N	TIN
Rathbun Creek – Site 6 First Flush (FF)			
Average	593	2183	513
Median	320	1600	400
Number of samples	23	23	23
Max	3600	8300	1800
Rathbun Creek – Site 6 Main Program (MP)			
Average	640	2041	514
Median	490	1600	450
Number of samples	22	22	22
Max	3800	7200	1800
Rathbun Creek – Site 7 First Flush (FF)			
Average	393	1950	795
Median	155	1850	750
Number of samples	22	22	22
Max	3700	5300	1900
Rathbun Creek – Site 7 Main Program (MP)			
Average	340	1919	786
Median	220	1900	800
Number of samples	21	21	21
Max	1300	4100	1900

TMDL Monitoring

Starting in June 2001, a program of monthly nutrient monitoring at seven tributary stations was initiated as part of the nutrient Total Maximum Daily Load (TMDL) process and is presently ongoing. The seven main tributary monitoring sites are Metcalf Creek at Highway 18 (MWDC1), Bear Creek Outlet (MWDC2), Grout Creek at Highway 38 (MWDC3), Rathbun Creek at the mouth (MWDC4), Summit Creek at Swan Dr. (MWDC5), Rathbun Creek at the zoo (MWDC6), Summit Creek below the ski area parking lot (MWDC7), and Knickerbocker Creek (MWDC8a) (Figure 2-1 – main document). Data from June 2001 to February 2003 are included in the analysis for the 303(d) listed tributary sampling stations (i.e., MWDC3, MWDC4, MWDC5, MWDC6, and MWDC7). Grab, first flush and flow composite samples were analyzed for total nitrogen, total dissolved nitrogen, ammonia-N, nitrate plus nitrite-N, total phosphorus, total dissolved phosphorus and orthophosphate-P.

As shown in Table A-6, these data were evaluated against the nutrient narrative objectives. Unionized ammonia could not be calculated because temperature was not determined at the time of sampling. Values of total phosphorus and total nitrogen are much higher than those observed in Big Bear Lake.

Table A-6. Nutrient concentrations (µg/L) for the 303(d) listed creeks (June 2001- February 2003)

Site	Type of sampling	Total P	Total N	TIN
Rathbun Creek at the mouth (MWDC4)	Grab			
Average		1685	1102	305
Median		1685	1102	305
Number of samples		2	2	2
Max		1842	1114	339
Rathbun Creek at the mouth (MWDC4)	First flush			
Average		1261	2176	719
Median		1303	2244	715
Number of samples		4	4	4
Max		1767	2789	916
Rathbun Creek at the mouth (MWDC4)	Flow composite			
Average		1081	2520	1038
Median		1157	1881	832
Number of samples		4	4	4
Max		1488	4817	2054
BMZoo on Rathbun Creek (MWDC6)	Grab			
Average		102	3174	2613
Median		108	3343	2793
Number of samples		4	4	4
Max		134	4582	3875
Grout Creek at Hwy 38 (MWDC3)	First Flush	1680	1719	98
Grout Creek at Hwy 38 (MWDC3)	Flow composite	935	1224	126
Table A-6 cont'd				
Summit Creek at Swan Dr. (MWDC5)	Grab			

Table A-6 cont'd

Average		141	1190	842
Median		36	219	23
Number of samples		5	5	5
Max		507	4236	3730
Summit Creek at Swan Dr. (MWDC5)	First Flush	961	1923	581
Summit Creek at Swan Dr. (MWDC5)	Flow composite			
Average		886	2200	859
Median		886	2200	859
Number of samples		2	2	2
Max		1094	2404	883
Summit Creek PK West (MWDC7)	Grab			
Average		562	3427	2263
Median		209	3395	1980
Number of samples		3	3	3
Max		1312	4098	2915

TIN was calculated by summing the individual values of nitrate + nitrite and ammonia.

Hydrology of the Rathbun Creek, Summit Creek, and Grout Creek subwatersheds

Shown in Figures A-1 and A-2 are the total annual simulated flows and average monthly simulated flows in AF for Rathbun, Summit, and Grout Creeks. The wettest year for the 14-year period, 1990-2003, was 1993. The majority of the flows occur during the winter with February contributing the greatest loads (Figure A-2). For the past few years, runoff due to precipitation and snowmelt has been the lowest in years. Since the inception of the TMDL monitoring effort in 2001, there has been no detectable flow in Grout Creek until the winter of 2003. Rathbun Creek and Summit Creek have also only been sampled on a few occasions because of the lack of flow.

Rathbun Creek, Summit Creek, and Grout Creek comprise approximately 18%, 2%, and 13%, respectively, of the total Big Bear Lake watershed area. These three subwatersheds contribute a third of the total runoff to the lake.

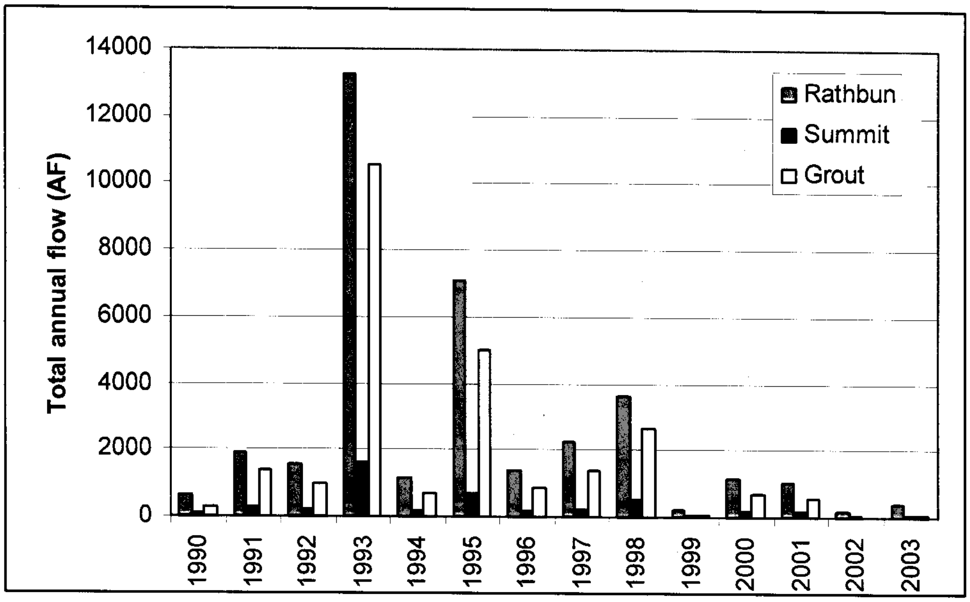


Figure A-1: Total annual simulated flow from HSPF land uses for Rathbun Creek, Summit Creek, and Grout Creek, 1990-2003 (WY)

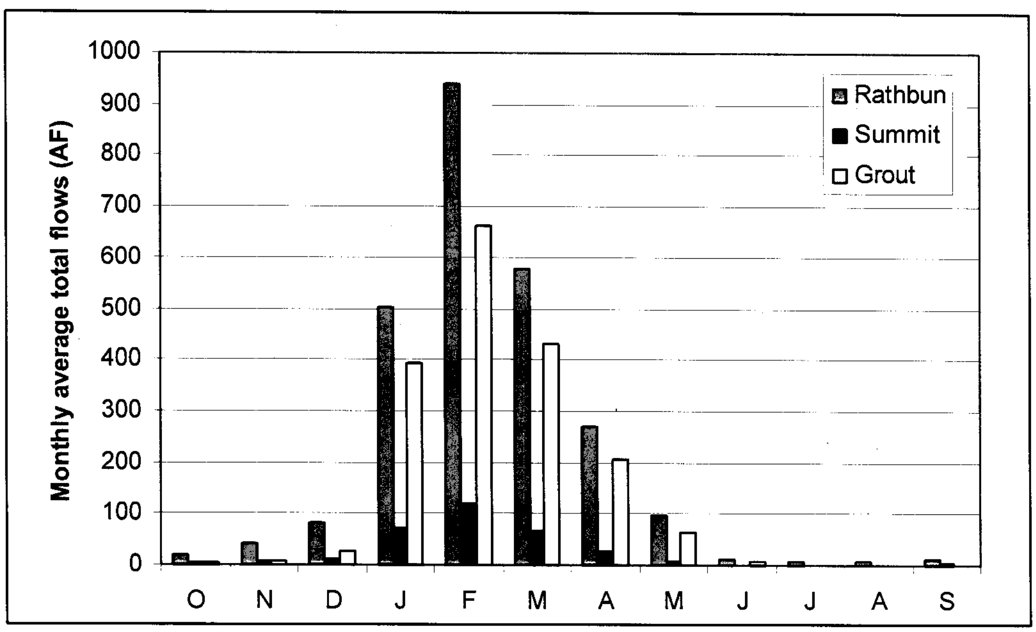


Figure A-2: Monthly trends of average total flow for Rathbun Creek, Summit Creek, and Grout Creek, 1990-2003 (WY)

Nutrient loads

Annual total nitrogen and total phosphorus loads to Rathbun Creek, Summit Creek, and Grout Creek subwatersheds for 1990 to 2003 are shown in Table A-7. Nutrient loads to these tributaries were not actually simulated due to the lack of monitoring data for model calibration. Instead, a ratio of subwatershed area to the total Big Bear Lake watershed area was determined for each pervious/impervious land use of the three tributaries (see Table 1-3 in the main document). This weighted percentage was then multiplied by the total nutrient loads to Big Bear Lake for each land use to obtain total phosphorus and total nitrogen loads for the different land uses for the three creeks.

The average percent contribution on an annual basis for Rathbun Creek, Summit Creek, and Grout Creek was 27%, 6%, and 3%, respectively, for total nitrogen and 21%, 4%, and 6%, respectively, for total phosphorus for the period, 1999-2003 (Table A-7).

Table A-7. Simulated annual total nutrient loads to the 303(d) listed tributaries for the 14 year period, 1990-2003 (WY)

WATER YEAR*	CREEK	TP LOAD (LBS)	BIG BEAR LAKE TP LOAD (LBS)	PERCENTAGE OF TP ANNUAL LOAD	TN LOAD (LBS)	BIG BEAR LAKE TN LOAD (LBS)	PERCENTAGE OF TN ANNUAL LOAD
1990	RATHBUN	95	455	21%	1316	4806	27%
1991		361	1814	20%	5728	18471	31%
1992		200	955	21%	3892	12508	31%
1993		15877	98016	16%	39910	130850	31%
1994		163	779	21%	2941	9719	30%
1995		3412	20995	16%	15529	58746	26%
1996		292	1324	22%	2545	8512	30%
1997		503	2207	23%	4212	13555	31%
1998		1358	7693	18%	9860	31130	32%
1999		70	326	21%	569	2574	22%
2000		382	1845	21%	2280	7854	29%
2001		137	650	21%	2585	8451	31%
2002		53	248	21%	433	1958	22%
2003		73	343	21%	600	2710	22%
1999-2003 AVERAGE		**143**	**682**	**21%**	**1293**	**4709**	**27%**
1990-2003 AVERAGE		1641	9832	17%	6600	22275	30%
MAX		15877	98016		39910	130850	
MIN		53	248		433	1958	
1990	SUMMIT	18	455	4%	274	4806	6%
1991		68	1814	4%	1142	18471	6%
1992		34	955	4%	779	12508	6%
1993		2220	98016	2%	7295	130850	6%
1994		29	779	4%	592	9719	6%
1995		600	20995	3%	2779	58746	5%
1996		49	1324	4%	476	8512	6%
1997		71	2207	3%	784	13555	6%

Table A-7 cont'd

1998		257	7693	3%	1904	31130	6%
1999		14	326	4%	116	2574	5%
2000		65	1845	4%	449	7854	6%
2001		24	650	4%	526	8451	6%
2002		11	248	4%	88	1958	5%
2003		15	343	4%	122	2710	5%
1999-2003 AVERAGE		**26**	**682**	**4%**	**260**	**4709**	**6%**
1990-2003 AVERAGE		248	9832	3%	1238	22275	6%
MAX		2220	98016		7295	130850	
MIN		11	248		88	1958	
1990	GROUT	19	455	4%	155	4806	3%
1991		110	1814	6%	753	18471	4%
1992		63	955	7%	532	12508	4%
1993		13660	98016	14%	7084	130850	5%
1994		46	779	6%	386	9719	4%
1995		2089	20995	10%	2863	58746	5%
1996		108	1324	8%	449	8512	5%
1997		210	2207	10%	746	13555	6%
1998		729	7693	9%	1460	31130	5%
1999		6	326	2%	47	2574	2%
2000		161	1845	9%	363	7854	5%
2001		38	650	6%	324	8451	4%
2002		5	248	2%	36	1958	2%
2003		7	343	2%	50	2710	2%
1999-2003 AVERAGE		**43**	**682**	**6%**	**164**	**4709**	**3%**
1990-2003 AVERAGE		1232	9832	13%	1089	22275	5%
MAX		13660	98016		7084	130850	
MIN		5	248		36	1958	

* A water year runs from October 1 through September 30 of the next year.

Figures A-3 and A-4 show nutrient loads from forest, resort and urban land uses for the three creeks during two different periods. The percentages of average total P and total N contributed by the three land uses for each creek varies for both periods. The forest land use contributes the greatest total N and total P loads for Grout Creek which has no resort land use, while the resort and urban land uses (residential and high density urban (HDU) combined) contribute the greatest total nitrogen and total phosphorus loads to Summit Creek. The urban land use contributes the majority of total P loads to Rathbun Creek while the urban and resort land uses contribute the majority of total N loads to this creek.

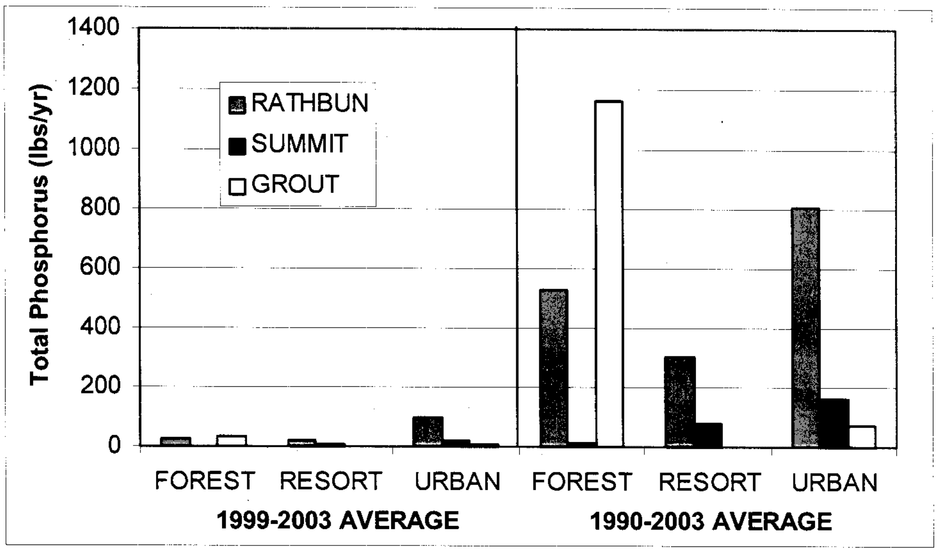


Figure A-3: Percentage of average total phosphorus for HSPF model land uses for each 303(d) listed tributary during a 5-yr period, 1999-2003, and 14-yr period, 1990-2003

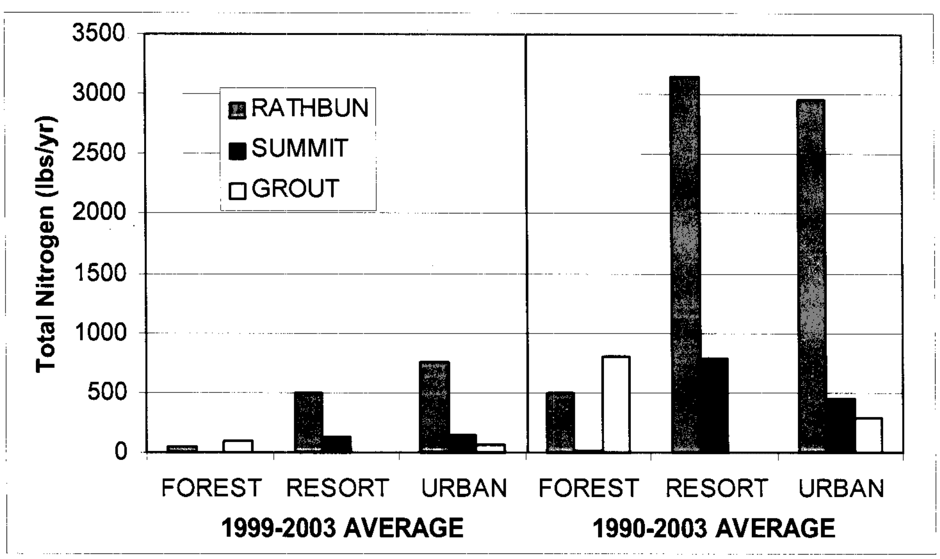


Figure A-4: Percentage of average total nitrogen for HSPF model land uses for each 303(d) listed tributary during a 5-yr period, 1999-2003, and 14-yr period, 1990-2003

Nutrient sources and corresponding loads for the three tributaries are summarized in Tables A-8, A-9 and A-10. Rathbun Creek contributes the highest nutrient loads of any of the three creeks which is in agreement with previous studies (Courtier and Smythe 1994; Siegfried and Herrgesell 1979a, 18). Resort and urban loads contribute 35% and 54% of the total nitrogen loads to Rathbun Creek for the last 5 years (1999-2003) (Table A-8). During a wet year (i.e., 1993), total nitrogen loads are 37 times the amount for resort and 23 times the amount for urban land uses observed during 1999-2003. The average annual total phosphorus loads during a wet year (i.e., 1993) are 23 times the amount for forest land uses during the last five years, 1999-2003.

Table A-8. Total nutrient loads to Rathbun Creek in lbs

Parameter	Forest NPS Load[1]	Resort NPS Load[2]	External Point Source Load[3]	Total Measured Load[4]
1990-2003				
TOTAL NITROGEN	858	3,276	3,217	7,351
% OF TOTAL	11.7%	44.6%	43.8%	
TOTAL PHOSPHORUS	2,729	1,125	2,841	6,695
% OF TOTAL	40.8%	16.8%	42.4%	
EXTREME WET EVENT (1993)				
TOTAL NITROGEN	4,509	19,740	19,288	43,537
% OF TOTAL	10.4%	45.3%	44.3%	
TOTAL PHOSPHORUS	15,683	7,285	18,621	41,589
% OF TOTAL	37.7%	17.5%	44.8%	
EXTREME DRY EVENT (1999-2003)				
TOTAL NITROGEN	159	537	826	1,522
% OF TOTAL	10.4%	35.3%	54.3%	
TOTAL PHOSPHORUS	683	313	660	1,656
% OF TOTAL	41.2%	18.9%	39.9%	

[1]Forest nonpoint source load = HSPF simulated loads from Forest North and Forest South land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[2]Resort nonpoint source load = HSPF simulated loads from Resort land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[3]External point source load = HSPF simulated loads from residential and high density urban land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[4]Total measured load = sum of items 1-3

Table A-9. Total nutrient loads to Summit Creek, in lbs.

Parameter	Forest NPS Load[1]	Resort NPS Load[2]	External Point Source Load[3]	Total Measured Load[4]
1990-2003				
TOTAL NITROGEN	22	813	488	1,323
% OF TOTAL	1.7%	61.5%	36.9%	
TOTAL PHOSPHORUS	69	279	545	893
% OF TOTAL	7.7%	31.2%	61.0%	
EXTREME WET EVENT (1993)				
TOTAL NITROGEN	115	4,896	2,757	7,768
% OF TOTAL	1.5%	63.0%	35.5%	
TOTAL PHOSPHORUS	383	1,807	3,748	5,938
% OF TOTAL	6.4%	30.4%	63.1%	
EXTREME DRY EVENT (1999-2003)				
TOTAL NITROGEN	4	133	147	284
% OF TOTAL	1.4%	46.8%	51.8%	
TOTAL PHOSPHORUS	17	78	107	202
% OF TOTAL	8.4%	38.6%	53.0%	

[1]Forest nonpoint source load = HSPF simulated loads from Forest North and Forest South land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[2]Resort nonpoint source load = HSPF simulated loads from Resort land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[3]External point source load = HSPF simulated loads from residential and high density urban land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[4]Total measured load = sum of items 1-3

The majority of loads for all three scenarios for both total phosphorus and total nitrogen for the Summit Creek subwatershed are from the resort and urban land uses. The forest land use contributes less than 2% of the total nitrogen loads and less than 10% of the total phosphorus loads.

Table A-10. Total nutrient loads to Grout Creek, in lbs.

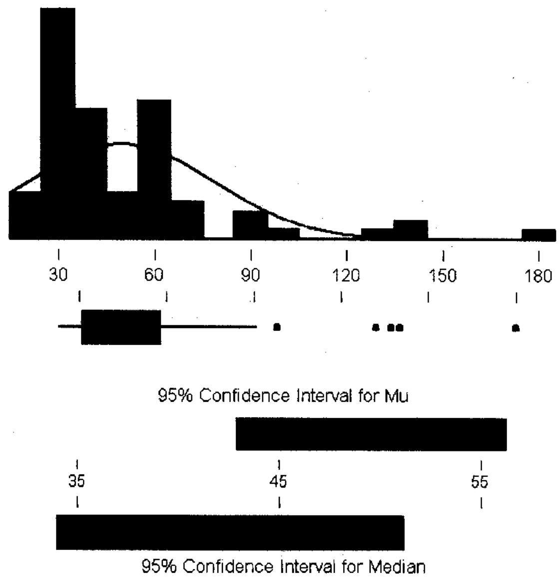
Parameter	Forest NPS Load[1]	Resort NPS Load[2]	External Point Source Load[3]	Total Measured Load[4]
1990-2003				
TOTAL NITROGEN	1,251	0	309	1,560
% OF TOTAL	80.2%	0.0%	19.8%	
TOTAL PHOSPHORUS	4,747	0	252	4,999
% OF TOTAL	95.0%	0.0%	5.0%	
EXTREME WET EVENT (1993)				
TOTAL NITROGEN	7,553	0	1,881	9,434
% OF TOTAL	80.1%	0.0%	19.9%	
TOTAL PHOSPHORUS	31,869	0	1,616	33,485
% OF TOTAL	95.2%	0.0%	4.8%	
EXTREME DRY EVENT (1999-2003)				
TOTAL NITROGEN	235	0	75	310
% OF TOTAL	75.8%	0.0%	24.2%	
TOTAL PHOSPHORUS	1,170	0	62	1,232
% OF TOTAL	95.0%	0.0%	5.0%	

[1]Forest nonpoint source load = HSPF simulated loads from Forest North and Forest South land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[2]Resort nonpoint source load = HSPF simulated loads from Resort land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[3]External point source load = HSPF simulated loads from residential and high density urban land uses; average of 1990-2003 loads used for average scenario; 1993 loads used for wet event; average of 1999-2003 loads used for dry event
[4]Total measured load = sum of items 1-3

There are no loads from resort land uses in the Grout Creek subwatershed. Over 95% of the total phosphorus loads for all three hydrological conditions are from forest land use. Total nitrogen loads are from forest land use (80%) with the remainder from urban land use.

Appendix B – Minitab results

Descriptive Statistics

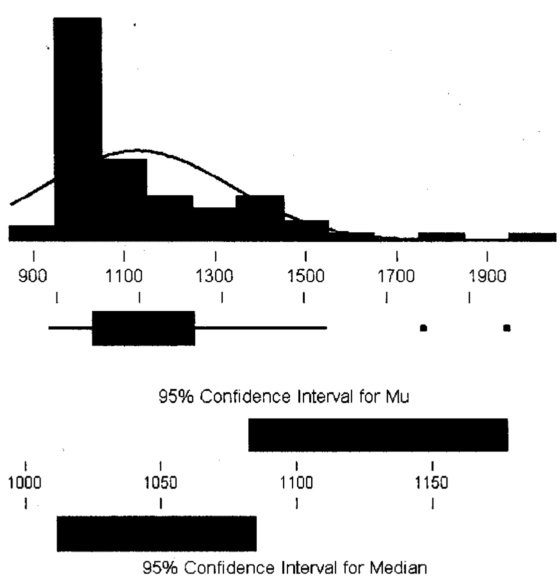


Variable: Total P

Anderson-Darling Normality Test	
A-Squared:	4.963
P-Value:	0.000
Mean	49.5921
StDev	29.1727
Variance	851.045
Skewness	2.31125
Kurtosis	6.45396
N	76
Minimum	23.000
1st Quartile	31.000
Median	42.000
3rd Quartile	57.750
Maximum	180.000
95% Confidence Interval for Mu	
42.926	56.258
95% Confidence Interval for Sigma	
25.159	34.722
95% Confidence Interval for Median	
34.000	51.101

Figure B1. Total P Descriptive Statistics

Descriptive Statistics



Variable: Total N

Anderson-Darling Normality Test	
A-Squared:	4.749
P-Value:	0.000
Mean	1130.26
StDev	208.02
Variance	43274.4
Skewness	1.76539
Kurtosis	3.67605
N	76
Minimum	883.00
1st Quartile	989.00
Median	1049.50
3rd Quartile	1232.25
Maximum	1992.00
95% Confidence Interval for Mu	
1082.73	1177.80
95% Confidence Interval for Sigma	
179.40	247.60
95% Confidence Interval for Median	
1011.97	1084.71

Figure B2. Total N Descriptive Statistics

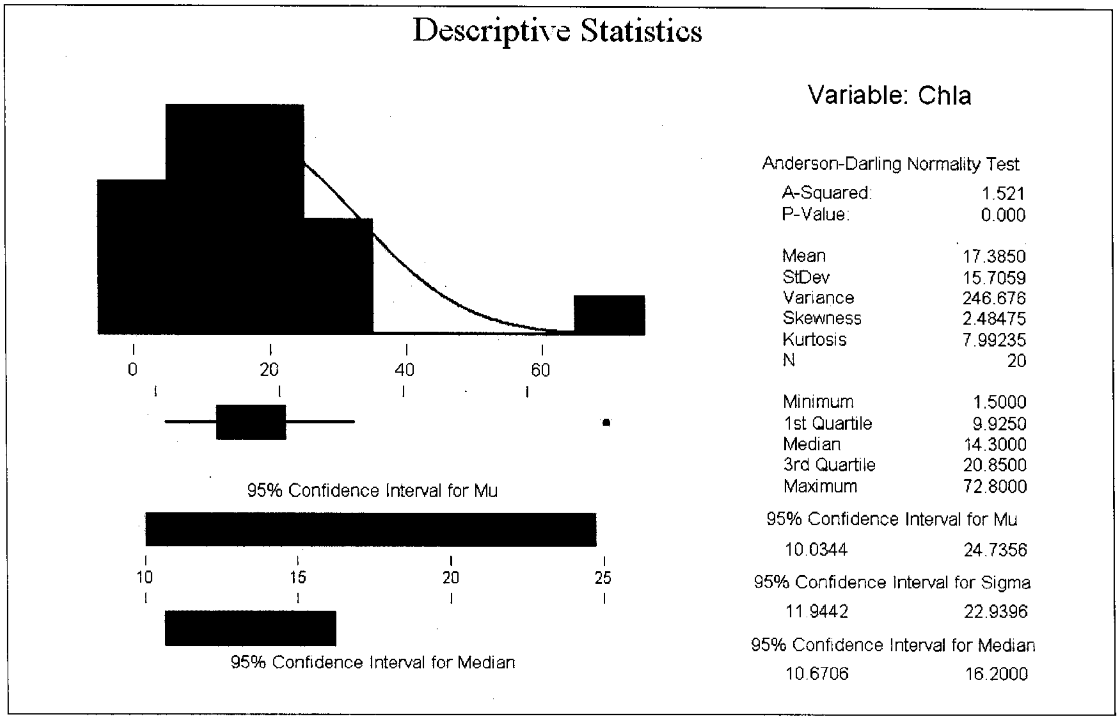


Figure B3. Chlorophyll a Descriptive Statistics

TMDL Summary for Numeric Targets

Worksheet size: 100000 cells
Saving file as: E:\MTBWIN\Data\TMDL_numtargets_0102.MPJ

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Total P	76	49.59	42.00	45.37	29.17	3.35
Total N	76	1130.3	1049.5	1107.7	208.0	23.9

Variable	Minimum	Maximum	Q1	Q3
Total P	23.00	180.00	31.00	57.75
Total N	883.0	1992.0	989.0	1232.2

Executing from file: E:\MTBWIN\MACROS\Describe.MAC

Descriptive Statistics

Variable	N	Mean	Median	TrMean	StDev	SE Mean

```
Chla                     38       12.63       10.00       10.90       12.59
2.04

Variable          Minimum      Maximum          Q1          Q3
Chla                 1.50        72.80        5.00       15.30

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Saving file as: E:\MTBWIN\Data\TMDL_numtargets_0102.MPJ
* NOTE  * Existing file replaced.

Worksheet size: 100000 cells
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Saving file as: E:\MTBWIN\Data\TMDL_numtargets_0102.MPJ
* NOTE  * Existing file replaced.

Descriptive Statistics


Variable                N        Mean      Median      TrMean       StDev
SE Mean
Chla                   20       17.38       14.30       15.19       15.71
3.51

Variable          Minimum      Maximum          Q1          Q3
Chla                 1.50        72.80        9.92       20.85

Executing from file: E:\MTBWIN\MACROS\Describe.MAC

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Welcome to Minitab, press F1 for help.
Retrieving project from file: O:\Planning\HBoyd\Data\Big Bear
TMDLs\Data\Nutrients\Statistical_Analyses\TMDL_numtargets_0102.MPJ
```

Minitab Project for determining 25% for TMDL numeric targets

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Worksheet size: 100000 cells
Saving file as: E:\MTBWIN\Data\TMDL_numtargets_0102.MPJ

Descriptive Statistics


Variable                N        Mean      Median      TrMean       StDev
SE Mean
Total P                76       49.59       42.00       45.37       29.17
3.35
Total N                76      1130.3      1049.5      1107.7       208.0
23.9

Variable          Minimum      Maximum          Q1          Q3
Total P             23.00       180.00       31.00       57.75
Total N             883.0       1992.0       989.0      1232.2

Executing from file: E:\MTBWIN\MACROS\Describe.MAC
```

```
Descriptive Statistics


Variable                 N        Mean      Median      TrMean        StDev
SE Mean
Chla                    38       12.63       10.00       10.90        12.59
2.04

Variable           Minimum     Maximum          Q1          Q3
Chla                  1.50       72.80        5.00       15.30

Executing from file: E:\MTBWIN\MACROS\Describe.MAC
Saving file as: E:\MTBWIN\Data\TMDL_numtargets_0102.MPJ
* NOTE  * Existing file replaced.

Worksheet size: 100000 cells
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Saving file as: E:\MTBWIN\Data\TMDL_numtargets_0102.MPJ
* NOTE  * Existing file replaced.

Descriptive Statistics


Variable                 N        Mean      Median      TrMean        StDev
SE Mean
Chla                    20       17.38       14.30       15.19        15.71
3.51

Variable           Minimum     Maximum          Q1          Q3
Chla                  1.50       72.80        9.92       20.85

Executing from file: E:\MTBWIN\MACROS\Describe.MAC

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Welcome to Minitab, press F1 for help.
Retrieving project from file: O:\Planning\HBoyd\Data\Big Bear
TMDLs\Data\Nutrients\Statistical_Analyses\TMDL_numtargets_0102.MPJ
```

Data that were used to determine nutrient numeric targets (all in µg/L)- photic and bottom data from June 12, 2001 to April 29, 2002 (Total P and Total N) and Growing season values (photic only) for Chla (June 2001- October 2001) – percentiles in Minitab

Total P	Total N	Chla
26	1016	2.9
25	985	9.7
43	883	15
61	1396	13
57	1420	10.9
36	1052	1.5
34	963	10.6

30	1035	11.5
24	981	13.6
31	974	15.3
23	1073	4.1
35	1000	16.2
41	1011	32.1
58	1271	16.2
57	1235	15.6
43	1047	4.1
30	1012	22.4
24	1055	72.8
25	989	31.6
27	957	28.6
54	958	
63	1195	
43	1517	
62	1555	
55	1126	
28	999	
26	1084	
25	981	
31	952	
59	1105	
58	1288	
67	1397	
91	1992	
66	1188	
41	1084	
39	1052	
33	1021	
31	978	
57	1224	
46	1003	
39	1119	
137	1789	
72	1365	
98	1314	
24	951	
24	989	
27	989	
28	996	
31	1017	
43	952	
56	1460	
54	1182	
60	1070	
44	1060	
55	993	

32	980
40	1105
34	939
56	1021
51	1254
180	1197
66	1293
140	1440
34	993
35	983
32	1055
28	962
47	951
56	1381
132	1373
87	1471
86	1161
33	1020
25	1040
34	1008
44	973

Appendix C – Trophic State Indices

Trophic State Indices. Trophic state indices characterize lakes based on nutrient concentrations, chlorophyll *a* concentrations, secchi disk transparency and other parameters. The most widely known is Carlson's Trophic State Index (TSI) which compares chlorophyll *a* concentration, secchi disk transparency, and total phosphorus concentration. This index was developed for lakes that are phosphorus limited. An index is obtained for each of the three parameters and these indices allow for comparisons of the trophic status of lakes. These indices should not be averaged (Carlson 1977). The following expressions use Carlson's method to calculate the TSI (Carlson and Simpson 1996, as cited in USEPA 2000b):

$$TSI\ (CHL) = 30.6 + 9.81 \ln(CHL) \quad \text{(chlorophyll } a\text{, in mg/m}^3\text{)}$$
$$TSI\ (SD) = 60 - 14.41 \ln(SD) \quad \text{(secchi disk readings, in m)}$$
$$TSI\ (TP) = 4.15 + 14.42 \ln(TP) \quad \text{(total phosphorus, in mg/m}^3\text{)}$$

Carlson's index uses algal biomass as the basis for trophic state classification. Chlorophyll *a*, secchi depth, and total phosphorus independently estimate algal biomass. The trophic continuum is based on a log transformation of secchi disk values. Carlson's index ranges from 0-100 and each 10-unit division of the index corresponds to a halving or doubling of secchi depth. Total phosphorus is usually inversely correlated with transparency and so a doubling of the total phosphorus usually corresponds to a halving of secchi depth. Chlorophyll *a* is a better predictor of algal biomass than total phosphorus or secchi depth. A northern temperate lake would be classified as oligotrophic with a TSI below 30, mesotrophic with a TSI between 40 and 50, and eutrophic with a TSI between 50-60. A TSI index above 70 characterizes hypereutrophic lakes (Carlson and Simpson 1996, as cited in USEPA 2000b). As shown in Table C-1, Big Bear Lake falls under eutrophic, but borders on hypereutrophic status.

Table C-1. Carlson's Trophic State Index for Big Bear Lake

	TSI (TP)	TSI(chla)	TSI (TN)	TSI(SD)
Minimum	53	35	53	40
Maximum	64	73	64	61
Mean	56	55	56	50

Note: The values used to calculate the TP, TN, and SD indices were from 6/01 to 4/02 prior to any herbicide treatment. The chla values were from 6/01 to 10/01 which corresponds to the growing season and were obtained prior to any herbicide application.

Other researchers added a nitrogen index to be used when water bodies were nitrogen limited (Kratzer and Brezonik 1981, as cited in USEPA 2000b). The formula used to calculate this nitrogen index is shown below:

$$TSI(TN) = 54.45 + 14.43 \ln(TN) \quad \text{(nitrogen values must be in mg/L)}$$

Variations in this index as well as Carlson's phosphorus index simultaneously might indicate that neither nitrogen or phosphorus are limiting, while variations in only Carlson's phosphorus index might indicate nitrogen limitation (Carlson and Simpson 1996, as cited in USEPA 2000b). As seen in Table C-1, three of the TSI indices are very similar while the secchi depth TSI is somewhat lower. Because the indices are similar, it implies that the lake is phosphorus limited and that algae dominate light attenuation (Carlson and Simpson 1996, as cited in USEPA 2000b).

Carlson's TSI is based only on algal biomass and does not account for macrophyte biomass. If the lake is macrophyte-dominated, the trophic state could be underestimated using Carlson's index. For example, Canfield et al. (1983) using Carlson's TSI classified one lake in Florida as oligotrophic, even though hydrilla covered 80% of the lake. The loss of hydrilla in the lake shifted the system to plankton and only then did Carlson's TSI classify the lake as eutrophic. To account for macrophytes, Canfield et al. 1983 developed an equation to estimate the total submersed macrophyte biomass in a lake. The equation is:

TSMB = SA x C x B
TSMB = total submersed macrophyte biomass (kilograms)
SA = lake surface area (square meters)
C = percent cover of submersed aquatic macrophytes
B = average biomass collected with a sampler (kilograms/square meter)

To then estimate the total amount of phosphorus associated with macrophytes, the variables in the equation above were used with the measured total phosphorus content in plant tissue. The total phosphorus in the macrophytes is summed with the total phosphorus estimated in the water column to obtain the total phosphorus content of the lake. This value can then be substituted into Carlson's TSI (TP) index. So, instead of just using water column concentration of total phosphorus, the relative contribution of phosphorus from the macrophytes will also be considered in calculating the trophic state of a lake. Because Big Bear Lake was classified as eutrophic using Carlson's TSI, it is not necessary to utilize the methodology of Canfield et al. (1983) in determining trophic state.

ATTACHMENT A

Resolution No.

To be submitted at a later date

ATTACHMENT A

Resolution No. R8–2005–0002

To be submitted at a later date

ATTACHMENT TO RESOLUTION NO. R8 2005–0002

(Proposed Basin Plan amendment changes are shown as in strikeout for deletions and underline for additions)

(NOTE: The following language is proposed to be inserted into Chapter 5 of the Basin Plan. If the amendments are approved, corresponding changes will be made to the Table of Contents, the List of Tables, page numbers, and page headers in the plan. Due to the two-column page layout of the Basin Plan, the location of tables in relation to text may change during final formatting of the amendments. For formatting purposes, the maps may be redrawn for inclusion in the Basin Plan, and the final layout may differ from that of the draft.)

Chapter 5 - Implementation Plan, Page 5-42

Big Bear Lake

Big Bear Lake, located in the San Bernardino Mountains, was created by the construction of the Bear Valley Dam in 1884. The Lake has a surface area of approximately 3,000 acres, a storage capacity ~~of 73,320~~of 73,320~~73,328~~ acre-ft and an average depth of 24 feet. The lake reaches its deepest point of 72 feet at the dam. The Big Bear Lake drainage basin encompasses 37 square miles and includes more than 10 streams. Local stream runoff and precipitation on the Lake are the sole source of water supply to the Lake. The spillway altitude is 6743.2~~6,744~~ feet. The major inflows to the lake are creeks, including Rathbone (Rathbun) Creek, Summit Creek, and Grout Creek. Outflow from the Lake is to Bear Creek, which ~~joins~~ is tributary to the Santa Ana River at about the 4000-foot elevation level. Twelve percent of Big Bear Lake's drainage basin consists of the Lake itself. The US Forest Service is the largest landowner in the Big Bear area. Two ski resorts, Bear Mountain and Snow Summit, lease land from the Forest Service.

The beneficial uses of Big Bear Lake include cold freshwater habitat (COLD), warm freshwater habitat (WARM), water contact recreation (REC1), non contact water recreation (REC2), municipal and domestic supply (MUN), agriculture supply (AGR), groundwater recharge (GWR), wildlife habitat (WILD) and rare, threatened or endangered species (RARE).

Big Bear Lake is moderately eutrophic. Deeper water during the summer months may exhibit severe oxygen deficits. Nutrient enrichment has resulted in the growth of ~~rooted~~ aquatic plants, which has impaired the fishing, boating, and swimming uses of the lake. To control this vegetation, mechanical harvesters are used to remove aquatic plants, including roots.

Toxics may be entering the Big Bear Lake watershed and accumulating in aquatic organisms and bottom sediments at concentrations that are of concern, not only for the protection of aquatic organisms, but for the protection of human health as well. Past Toxic Substances Monitoring Program data have indicated the presence of copper, lindane, mercury, ~~and~~ zinc, and PCBs in fish tissue.

During 1992-93, the Regional Board conducted a Phase I Clean Lakes study (Section 314 of the Clean Water Act) to evaluate the current water quality condition of the lake and its major tributaries [Ref. 20]. The focus of the study was to identify the tributaries responsible for inputs of toxics and nutrients. As a result of data in the Clean Lakes Study, Big Bear Lake and specific tributaries were placed on the 1994 Clean Water Act Section 303(d) List of Water Quality Limited Segments for the reasons indicated in Table 5-9a-b.

Table 5-9a-b

Big Bear Lake Watershed Waterbodies on the
1994 303(d) List of Impaired Waters

WATERBODY	STRESSOR
Big Bear Lake	nutrients
	noxious aquatic plants
	sedimentation/siltation
	metals
	copper
	mercury
Rathbone (Rathbun) Creek	nutrients
	sedimentation/siltation
Grout Creek	metals
	nutrients
Summit Creek	nutrients
Knickerbocker Creek	metals
	pathogens

In 2000, the Regional Board initiated development of Total Maximum Daily Loads for the Big Bear Lake watershed.

~~As in previous Big Bear Lake Studies, phosphorus was found to be the limiting nutrient. Approximately 80% of the phosphorous load emanates from Rathbone Creek. The large amount of precipitation in Southern California during 1993 resulted in more runoff from the Big Bear Lake tributaries and an increased input of nutrients. For instance, the total phosphorous load increased between 1992 to 1993 by a factor of 2, and the total nitrogen load by a factor of 100. Given the increasing eutrophic condition of the Lake, harvesting of aquatic vegetation may not be effective much longer. It is appropriate to implement control measures for reducing the input of nutrients from the major tributaries, Rathbone Creek and Grout Creek.~~

1. Big Bear Lake Nutrient Total Maximum Daily Loads (TMDLs) for Dry Hydrological Conditions

Past studies, starting in 1968/1969, have shown that Big Bear Lake is eutrophic and that the limiting nutrient is generally phosphorus. In Big Bear Lake, nutrients (nitrogen and phosphorus) are available in the water column and sediment and are taken up by aquatic macrophytes and algae. Nutrients are also bound in living and dead organic material, primarily macrophytes and algae. Decomposition of this organic material, as well as macrophyte and algal respiration, consumes dissolved oxygen, resulting in the depletion of dissolved oxygen from the water column. Oxygen depletion in the hypolimnion results in anoxic conditions, leading to periodic fish kills in Big Bear Lake. Oxygen depletion also results in the release of nutrients from the sediment into the water column, promoting more algae and aquatic macrophyte production. Nutrients released by plant decomposition are cycled back into a bioavailable form.

Although aquatic macrophytes provide protection from shoreline erosion, habitat for fish and other aquatic biota and waterfowl habitat, excessive growth of noxious and nuisance species, particularly Eurasian watermilfoil (*Myriophyllum spicatum*) impairs recreational uses of the Lake and reduces plant and animal species and habitat diversity.

A TMDL technical report prepared by Regional Board staff describes the nutrient related problems in Big Bear Lake in greater detail and discusses the technical basis for the TMDLs that follow [Ref. # 1].

1. A. Numeric Targets

As shown in Table 5-9a-c, both "causal and response" interim and final numeric targets are specified for Big Bear Lake. Causal targets are those for phosphorus and nitrogen, the principal nutrients responsible for plant growth. Phosphorus is the primary limiting nutrient in Big Bear Lake, and nitrogen can be a limiting nutrient under certain conditions. Response targets include macrophyte coverage, percentage of nuisance aquatic vascular plant species and chlorophyll *a* concentrations. These response targets are more direct indicators of impairment and are specified to assess and track water quality improvements in Big Bear Lake.

Table 5-9a-c

Big Bear Lake Nutrient TMDL Numeric Targets[a]

Indicator	**Target Value**
Total P concentration (interim)	Annual average[b] no greater than 35 µg/L; to be attained no later than 2010
Total P concentration (final)	Annual average[b] no greater than 20 µg/L; to be attained no later than 2015
Total N concentration (final)	Annual average[b] no greater than 1000 µg/L; to be attained no later than 2015
Macrophyte Coverage	30-60% on a total area basis; to be attained by 2015[c]
Percentage of Nuisance Aquatic Vascular Plant Species (final)	95% eradication on a total area basis of Eurasian Watermilfoil and any other invasive aquatic plant species; to be attained no later than 2015[c]
Chlorophyll *a* concentration (interim)	Growing season[d] average no greater than 10 µg/L; to be attained no later than 2010
Chlorophyll *a* concentration (final)	Growing season[d] average no greater than 5.0 µg/L; to be attained no later than 2015

[a] Compliance with the targets to be achieved as soon as possible, but no later than the date specified

[b] Annual average determined by the following methodology: the nutrient data from both the photic composite and discrete bottom samples are averaged by station number and time; a calendar year average is obtained for each sampling location; and finally, the separate annual averages for each location are averaged to determine the lake-wide average. The open-water sampling locations used to determine the annual average are MWDL1, MWDL2, MWDL6, and MWDL9 (see 1. E. Implementation, Task 4.2, Table 5-9a-i).

[c] Calculated as a 5-yr running average based on measurements taken at peak macrophyte growth as determined in the Aquatic Plant Management Plan (see 1.E. Implementation, Task 8)

[d] Growing season is the period from May 1through October 31of each year

1. B. Nutrient TMDLs, WLAs and LAs and Compliance Dates – Dry Hydrological Conditions

TMDLs, and the WLAs and LAs necessary to achieve them, are established for total phosphorus and total nitrogen for dry hydrological conditions only. As stated above, phosphorus and nitrogen are the nutrients that cause beneficial use impairment in Big Bear Lake. Dry hydrological conditions are defined by the conditions observed from 1999-2003; that is, average tributary inflow to Big Bear Lake ranging from 0 to 3,049 AF, average lake levels ranging from 6671 to 6735 feet and annual precipitation ranging from 0 to 23 inches. TMDLs, WLAs and LAs for wet and/or average hydrological conditions will be established as part of the TMDL Phase 2 activities once additional data have been collected (see 1.E. TMDL Implementation, Task 12, below).

The phosphorus and nitrogen TMDLs for Big Bear Lake for dry hydrological conditions are shown in Table 5-9a-d. Wasteload allocations for point source discharges and load allocations for nonpoint source discharges are shown in Table 5-9a-e.

Table 5-9a-d

Big Bear Lake Nutrient TMDLs for Dry Hydrological Conditions

	Total Phosphorus (lb/yr) [c]	**Total Nitrogen (lb/yr)** [c]
Interim TMDL[a]	26,012	N/A
Final TMDL[b]	21,735	280,900

[a] Interim compliance to be achieved as soon as possible, but no later than December 31, 2010.

[b] Final compliance to be achieved as soon as possible, but no later than December 31, 2015.

[c] Specified as an annual average for dry hydrological conditions only

Table 5-9a-e

Big Bear Lake
Nitrogen and Phosphorus Wasteload and Load Allocations for Dry Hydrological Conditions

Big Bear Lake Dry Conditions Nutrient TMDLs	**Interim Total Phosphorus Load Allocation (kg/yr)[a, c]**	**Final Total Phosphorus Load Allocation (kg/yr)[b, c]**	**Final Total Nitrogen Load Allocation (kg/yr)[b, c]**
TMDL	**26,012**	**21,735**	**280,900**
WLA	**475**	**475**	**3,445**
Urban	475	475	3,445
LA	**25,537**	**21,260**	**277,455**
Internal Sediment	8,555	4,278	152,386
Internal macrophyte	15,700	15,700	102,324
Atmospheric Deposition	1,074	1,074	21,474
Forest	175	175	460
Resort	33	33	811

[a] Interim allocation compliance to be achieved as soon as possible, but no later than December 31, 2010.
[b] Final allocation compliance to be achieved as soon as possible, but no later than December 31, 2015.
[c] Specified as an annual average for dry hydrological conditions only

1.C. Margin of Safety

The Big Bear Lake Nutrient TMDLs include an implicit margin of safety (MOS) as follows:

1. The derivation f numeric targets based on the 25th percentile of nutrient data;
2. The use of conservative assumptions in modeling the response of Big Bear Lake to nutrient loads.

1. D. Seasonal Variations/Critical Conditions

The critical condition for attainment of aquatic life and recreational uses in Big Bear Lake occurs during the summer and during dry years, when nutrient releases from the sediment are greatest and water column concentrations increase. Macrophyte biomass peaks in the summer/early fall. Recreational uses of the lake are also highest during the summer. These nutrient TMDLs for Big Bear Lake are focused on the critical dry hydrological conditions and, in particular, on the control of the internal sediment loads that dominate during these periods. These are the first phase of TMDLs needed to address eutrophication in Big Bear Lake. The next phase will include collection of data needed to refine the in-lake and watershed models and to develop TMDLs that address other hydrological conditions (see 1. E. TMDL Implementation).

The TMDLs recognize that different nutrient inflow and cycling processes dominate the lake during different seasons. These processes were simulated in the in-lake model using data collected during all seasons over a multi-year period. Thus, the model results reflect all seasonal variations. The numeric targets are expressed as annual averages. The intent is to set targets that will, when achieved, result in improvement of the trophic status of the Big Bear Lake year-round.

Compliance with numeric targets will ensure water quality improvements that prevent excessive algae blooms and fish kills, particularly during the critical summer period when these problems are most likely to occur.

1. E. TMDL Implementation

Table 5-9a-f outlines the tasks and schedules to implement the TMDL. Each of these tasks is described below.

Table 5-9a-f

Big Bear Lake Nutrient TMDL Implementation
Plan/Schedule Report Due Dates

Task	**Description**	**Compliance Date-As soon As Possible but No Later Than**
TMDL Phase 1		
Task 1	Establish New Waste Discharge Requirements for Nutrient Sources	*(*6 months after BPA approval*)*
Task 2	Establish New Waste Discharge Requirements for Lake Restoration Activities	*(*18 months after BPA approval*)*
Task 3	Revise Existing Waste Discharge Requirements	*(*6 months after BPA approval*)*
Task 4	Nutrient Water Quality Monitoring Program 4.1 Watershed-wide Nutrient Monitoring Plan(s) 4.2 Big Bear Lake Nutrient Monitoring Plan(s)	Plan/schedule due *(*3 months after BPA approval*)* Annual reports due February 15
Task 5	Atmospheric Deposition Determination	Plan/schedule due *(*1 year after BPA approval*)*
Task 6	Big Bear Lake and Watershed Model Updates	Plan/schedule due *(*6 months after BPA approval*)*
Task 7	Big Bear Lake In-Lake Sediment Nutrient Reduction Plan	Plan/schedule due *(*1 year after BPA approval*)*
Task 8	Big Bear Lake Aquatic Plant Management Plan	Plan/schedule due *(*1 year after BPA approval)** 5 year report due (**5 years after Regional Board approval of plan/schedule);* thereafter, annual reports due February 15
Task 99	Big Bear Lake Multimetric Index Development Plan	Plan/schedule due *(*1 year after BPA approval*)*
TMDL Phase 2		
Task 10	Review and Revise Nutrient Water Quality Objectives	December 31, 2010
Task 11	Review Big Bear Lake Tributary Data	December 31, 2008
Task 12	Develop TMDLs, WLAs and LAs for wet and/or average hydrological conditions	December 31, 2012
Task 13	Review of TMDLs/WLAs/LAs	Once every 3 years

[Note: BPA => Basin Plan Amendment]

Task 1: Establish New Waste Discharge Requirements for Nutrient Sources

On or before (**6 months from the effective date of this BPA*), the Regional Board shall issue the following new waste discharge requirements

1.1 Waste Discharge Requirements (WDRs) or Conditional Waiver of WDRs to the US Forest Service to incorporate the nutrient load allocations and monitoring and reporting requirements for Forested Area.

1.2 Waste Discharge Requirements (WDRs) or Conditional Waiver of WDRS to the Big Bear Mountain Resorts to incorporate the nutrient load allocation and monitoring and reporting requirements

Other nutrient discharges will be addressed and permitted as appropriate.

Task 2: Establish New Waste Discharge Requirements for Lake Restoration Activities

On or before (**18 months from the effective date of this BPA*), the Regional Board shall issue the following new waste discharge requirements

NPDES Permit to the US Forest Service, the State of California, Department of Transportation (Caltrans), the County of San Bernardino, San Bernardino County Flood Control District, the City of Big Bear Lake, and Big Bear Mountain Resorts for Lake restoration activities, including, but not limited to alum treatment and/or herbicide treatment. Requirements specified in these Waste Discharge Requirements, shall be developed using the Aquatic Plant Management Plan and Schedule submitted pursuant to Task 8.

Task 3: Review and/or Revise Existing Waste Discharge Requirements

Waste Discharge Requirements (WDRs) have been issued by the Regional Board regulating discharge of various types of wastes in the Big Bear Lake watershed. On or before (**6 months from the effective date of this Basin Plan amendment**), these WDRs shall be reviewed and revised as necessary to incorporate nutrient wasteload allocation and TMDL monitoring requirements.

3.1 Waste Discharge Requirements for the San Bernardino County Flood Control and Transportation District, the County of San Bernardino and the Incorporated Cities of San Bernardino County within the Santa Ana Region, Areawide Urban Runoff, NPDES No. CAS 618036 (Regional Board Order No. R8-2002-0012). The current Order has provisions to address TMDL issues. In light of these provisions, revision of the Order may not be necessary to address TMDL requirements.

3.2 State of California, Department of Transportation (Caltrans) Stormwater Permit
Provision E.1 of Order No. 99-06-DWQ requires Caltrans to maintain and implement a Storm Water Management Plan (SWMP). Annual updates of the SWMP needed to maintain an effective program are required to be submitted to the State Water Resources Control Board.

Provision E.2 of Order No. 99-06-DWQ requires Caltrans to submit a Regional Workplan by April 1 of each year for the Executive Officer's approval. As part of the annual update of the SWMP and Regional Workplan, Caltrans shall submit plans and schedules for conducting the monitoring and reporting requirements specified in Task 4 and the special studies required in Tasks 6, 7, 8 and 9.

Task 4: Monitoring

4.1 Watershed-wide Nutrient Water Quality Monitoring Program

No later than (**3 months from effective date of this Basin Plan amendment **), the US Forest Service, the State of California, Department of Transportation (Caltrans), the County of San Bernardino, San Bernardino County Flood Control District, the City of Big Bear Lake and Big Bear Mountain Resorts shall, as a group, submit to the Regional Board for approval a proposed watershed-wide nutrient monitoring program that will provide data necessary to review and update the Big Bear Lake Nutrient TMDLs, to determine specific sources of nutrients and to develop TMDLs for other hydrological conditions. Data to be collected and analyzed shall address, at a minimum, determination of compliance with the nitrogen and phosphorus dry condition TMDLs, including the WLAs and LAs.

At a minimum, the proposed plan shall include the collection of samples at the stations specified in Table 5-9a-g and shown in Figure 5-7, at the frequency specified in Table 5-9a-h. If one or more of these monitoring stations are not included, rationale shall be provided and proposed alternative monitoring locations shall be identified in the proposed monitoring plan. In addition to water quality samples, every two weeks on a year-round basis, visual monitoring (including documenting flow type and stage) determinations shall be made at all stations shown in Table 5-9a-h. Flow measurements will be required each time water quality samples are obtained.

At a minimum, samples shall be analyzed for the following constituents:

- total nitrogen
- nitrate + nitrite nitrogen
- total phosphorus
- total dissolved phosphorus
- total suspended solids (TSS)
- chlorophyll *a*
- dissolved oxygen
- alkalinity
- ammonia nitrogen
- total dissolved nitrogen
- ortho-phosphate (SRP)
- temperature
- turbidity
- pH
- conductivity
- hardness

Note: Chlorophyll *a* will only be collected and analyzed from May 1- October 31 of each year at the frequencies described in Table 5-9a-h; Bear Creek outlet will not be sampled for chlorophyll *a*

The proposed monitoring plan shall be implemented upon Regional Board approval at a duly noticed public meeting. An annual report summarizing the data collected for the year and evaluating compliance with the WLAs/LAs shall be submitted by February 15 of each year.

In lieu of this coordinated monitoring plan, one or more of the parties identified above may submit a proposed individual or group monitoring plan for Regional Board approval. Any such individual or group monitoring plan is due no later than (*3 *months from effective date of this Basin Plan amendment**) and shall be implemented upon Regional Board approval at a duly noticed public meeting. An annual report of data collected pursuant to approved individual/group plan(s) shall be submitted by February 15 of each year. The report shall summarize the data and evaluate compliance with the WLAs/LAs.

Table 5-9a-g

Big Bear Lake Watershed
Minimum Required Sampling Station Locations

Station Number	**Station Description**
MWDC2	Bear Creek Outlet
MWDC3	Grout Creek at Hwy 38
MWDC4	Rathbun Creek at Sandalwood Ave.
MWDC5	Summit Creek at Swan Dr.
MWDC6	Rathbun Creek below the Zoo
MWDC8	Knickerbocker Creek at Hwy 18
MWDC13	Boulder Creek at Hwy 18

Note: Bear Creek outlet to be sampled monthly from March -November

At a minimum, samples shall be analyzed at the frequencies specified in Table 5-9a-h:

Table 5-9a-h

Big Bear Lake Watershed
Sampling Frequency

Flow type	**Months monitoring is required**	**Frequency**
Baseflow	January 1 – December 31	Once/month when baseflow is present;
Snow melt	January 1 – May 31[1]	Varied -See note 2 below
Storm events	January 1 – December 31	3 storms per year[3]

[1] Sampling to begin after the first substantial snowfall resulting in an accumulation of 1.0 inch or more of snow

[2] Samples to be collected daily for the first three days of the snow melt period. If ambient air temperatures remain above freezing after three days have passed, snow melt sampling will then be performed once a week for the following three weeks or until the snow melt period ceases. Snow melt cessation will be determined by one of the following: a) ambient air temperatures drop below freezing during most of the day; or b) a storm/rain precipitation event occurs after the snow melt event was initiated. Beginning March 15th of each year, snow melt flows will most likely be continuous since ambient air temperatures will usually remain above freezing. From March 15th through May 31 of each year, snow melt sampling events will be conducted daily for the first two days of a snow melt event and then once a week thereafter until the spring runoff period has ended or the tributary station location shows no signs of daily flows for one week. Flow status will be evaluated in the afternoon, when ambient air temperatures are highest and flow potential is greatest.

[3] Two storm events to be sampled during October – March; 1 storm event to be sampled during April – September. For each storm event, eight samples across the hydrograph are to be collected.

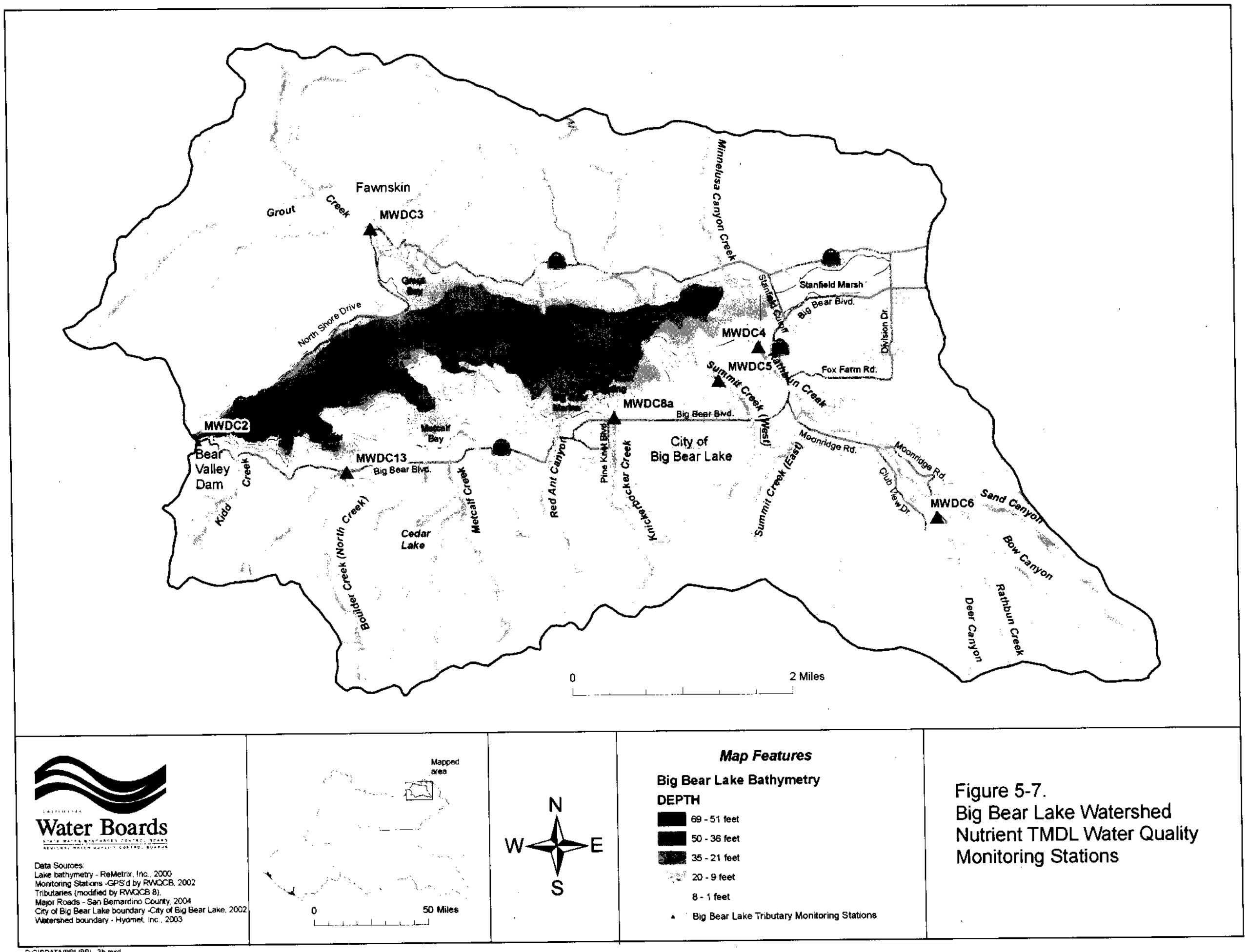

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Figure 5-7 – Big Bear Lake Watershed Nutrient TMDL Water Quality Stations

4.2 Big Bear Lake: In-Lake Nutrient Monitoring Program

No later than (**3 months from effective date of this Basin Plan amendment* *), the US Forest Service, the State of California, Department of Transportation (Caltrans), the County of San Bernardino, San Bernardino County Flood Control District, the City of Big Bear Lake, and Big Bear Mountain Resorts shall, as a group, submit to the Regional Board for approval a proposed Big Bear Lake nutrient monitoring program that will provide data necessary to review and update the Big Bear Lake Nutrient TMDLs, and to develop TMDLs for other hydrological conditions. Data to be collected and analyzed shall address, at a minimum: (1) determination of compliance with interim and final nitrogen, phosphorus and chlorophyll *a*, numeric targets; and (2) refinement of the in-lake model for the purposes of TMDL review and development.

At a minimum, the proposed plan shall include the collection of samples at the stations specified in Table 5-9a-i and shown in Figure 5-8, at the specified frequency indicated in Table 5-9a-i. With the exception of hardness, alkalinity, total organic carbon (TOC), dissolved organic carbon (DOC), and chlorophyll *a*, each sample to be analyzed shall be collected as a photic zone composite (from the surface to 2 times the secchi depth) and as a bottom discrete (0.5 meters off the surface bottom) sample. Hardness, alkalinity, TOC, DOC, and chlorophyll *a* shall be collected as photic zone composites. Dissolved oxygen, water temperature, turbidity, specific conductance, and pH shall be measured at 1-meter intervals from the surface to 0.5 meters from the bottom using a multi-parameter water quality meter. Water clarity shall be measured with a secchi disk.

At a minimum, in-lake samples must be analyzed for the following constituents:

- specific conductance
- water temperature
- chlorophyll *a*
- total nitrogen
- nitrate +nitrite nitrogen
- total phosphorus
- total hardness
- total dissolved phosphorus
- dissolved organic carbon (DOC)
- total dissolved nitrogen
- dissolved oxygen
- water clarity (secchi depth)
- ammonia nitrogen
- alkalinity
- turbidity
- ortho-phosphate (SRP)
- total suspended solids (TSS)
- pH
- total dissolved solids (TDS)
- total organic carbon (TOC)

The monitoring plan shall be implemented upon Regional Board approval at a duly noticed public meeting. An annual report summarizing the data collected for the year and evaluating compliance with the TMDL shall be submitted by February 15 of each year.

Table 5-9a-i

Big Bear Lake Minimum Required Sampling Station Locations

Station Number	**Station Description**
MWDL1	Big Bear Lake – Dam
MWDL2	Big Bear Lake – Gilner Point
MWDL6	Big Bear Lake – Mid Lake Middle
MWDL9	Big Bear Lake – Stanfield Middle

Frequency of sampling at all stations: for all constituents except TOC and DOC, monthly from March – November; bi-weekly (i.e., every other week) from June 1 through October 31. TOC and DOC to be monitored four times per year (quarterly) from January through December.

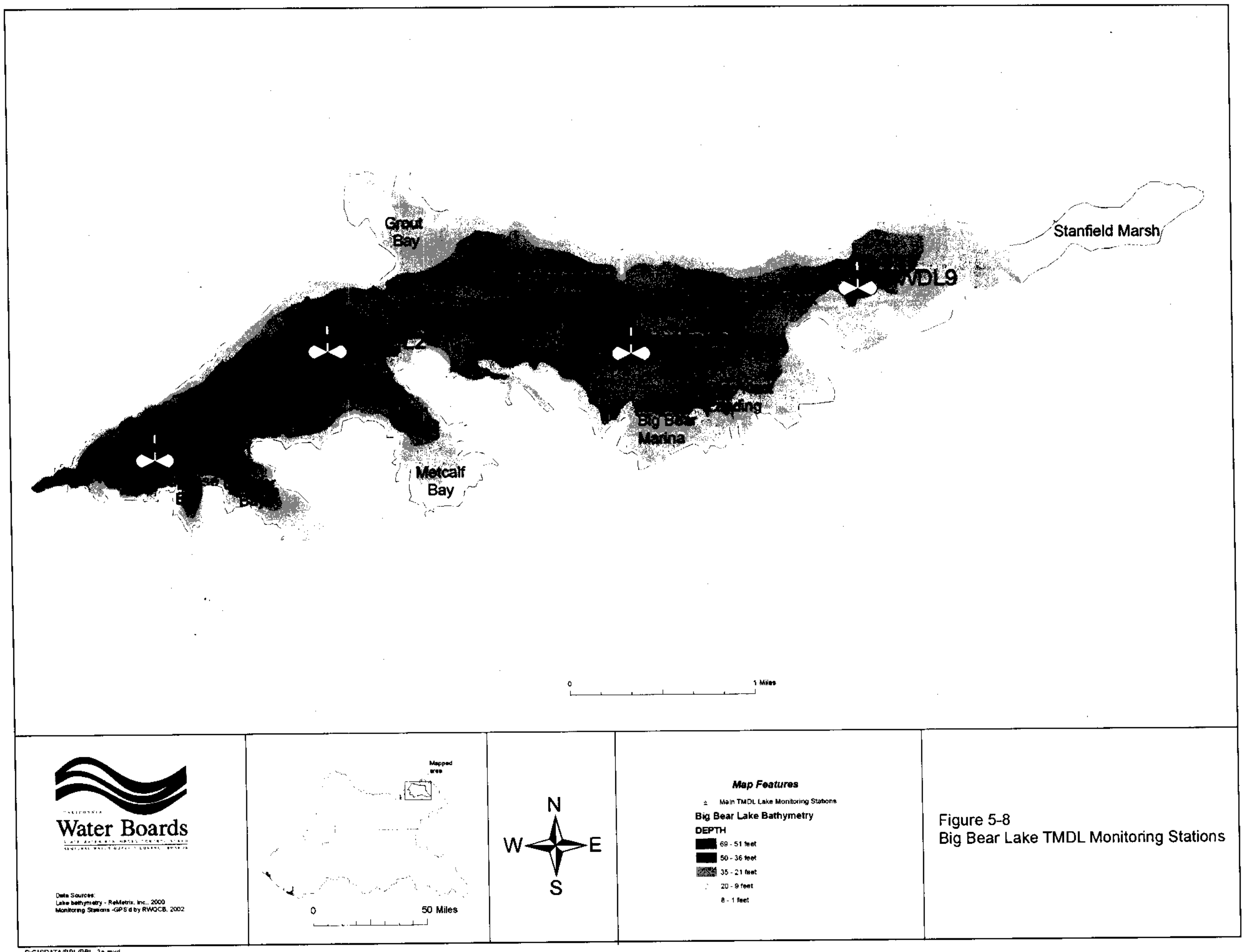

Figure 5-8 Big Bear Lake TMDL Monitoring Stations

In lieu of this coordinated monitoring plan, one or more of the parties identified above may submit a proposed individual or group monitoring plan for Regional Board approval. Any such individual or group monitoring plan is due no later than (*3 *months from effective date of this Basin Plan amendment* *) and shall be implemented upon Regional Board approval at a duly noticed public meeting. An annual report of data collected pursuant to approved individual/group plan(s), shall be submitted by February 15 of each year. The report shall summarize the data and evaluate compliance with the numeric targets.

Task 5: Atmospheric Deposition Determination

No later than (**1 year from effective date of this Basin Plan amendment* *), the Regional Board, in coordination with local stakeholders, the South Coast Air Quality Management District and the California Air Resources Board, shall develop a plan and schedule for quantifying atmospheric deposition of nutrients in the Big Bear Lake watershed.

Task 6: Update of Watershed and In-Lake Nutrient Models

No later than (**6 months from effective date of this Basin Plan amendment* *), the US Forest Service, the State of California, Department of Transportation (Caltrans), the County of San Bernardino, San Bernardino County Flood Control District, the City of Big Bear Lake, and Big Bear Mountain Resorts, shall, as a group, submit to the Regional Board for approval a proposed plan and schedule for updating the existing Big Bear Lake Watershed Nutrient Model and the Big Bear Lake in-lake nutrient model. The plan and schedule must take into consideration additional data and information that are or will be generated from the respective TMDL monitoring programs (Tasks 4. 1 and 4.2, above).

The plan for updating the Watershed and In-lake Models shall be implemented upon Regional Board approval at a duly noticed public meeting.

In lieu of this coordinated plan, one or more of the parties identified above may submit a proposed individual or group Watershed and In-lake Nutrient Model Update Plan for approval by the Regional Board. Any such individual or group Plan is due no later than (**6 months from effective date of this Basin Plan amendment**) and shall be implemented upon Regional Board approval at a duly noticed public meeting.

Task 7: Big Bear Lake Sediment Nutrient Reduction Plan

No later than (**1 year from effective date of this Basin Plan amendment* *), the US Forest Service, the State of California, Department of Transportation (Caltrans), the County of San Bernardino, San Bernardino County Flood Control District, the City of Big Bear Lake, and Big Bear Mountain Resorts, shall, as a group, submit to the Regional Board for approval a proposed plan and schedule for in-lake sediment nutrient reduction for Big Bear Lake. The proposed plan shall include an evaluation of the applicability of various in-lake treatment technologies to support development of a long-term strategy for control of nutrients from the sediment. The submittal shall also contain a proposed sediment nutrient monitoring program to evaluate the effectiveness of any strategies implemented.

The Big Bear Lake In-lake Sediment Nutrient Reduction Plan shall be implemented upon Regional Board approval at a duly noticed public meeting.

In lieu of this coordinated plan, one or more of the parties identified above may submit a proposed individual or group In-lake Sediment Nutrient Reduction Plan for approval by the Regional Board. Any such individual or group Plan is due no later than (**1 year from effective date of this Basin Plan amendment**) and shall be implemented upon Regional Board approval at a duly noticed public meeting.

Task 8: Big Bear Lake Aquatic Plant Management Plan

No later than (**1 year from effective date of this Basin Plan amendment* *), the US Forest Service, the State of California, Department of Transportation (Caltrans), the County of San Bernardino, San Bernardino County Flood Control District, the City of Big Bear Lake, and Big Bear Mountain Resorts, shall, as a group, submit to the Regional Board for approval a proposed plan and schedule for management of in-lake aquatic plants (macrophytes). The proposed plan shall include an evaluation of the applicability of various in-lake treatment technologies to control the presence of noxious and nuisance aquatic plants. The plan shall also include monitoring and tracking aquatic plants. Data to be collected and analyzed shall address, at a minimum, determination of compliance with the final numeric targets for macrophyte coverage and percentage of nuisance aquatic vascular plant species (see 1.B, above).

The Big Bear Lake Aquatic Plant Management Plan shall be implemented upon Regional Board approval at a duly noticed public meeting. A report summarizing the data collected each year during the initial 5-year period and evaluating compliance with the numeric targets shall be submitted by February 15 after the first 5-year period. Thereafter, the report shall be submitted annually by February 15 of each year.

In lieu of this coordinated plan, one or more of the parties identified above may submit a proposed individual or group Aquatic Plant Management Plan for approval by the Regional Board. Any such individual or group Plan is due no later than (**1 year from effective date of this Basin Plan amendment**) and shall be implemented upon Regional Board approval at a duly noticed public meeting. A report summarizing the data collected each year during the initial 5-year period and evaluating compliance with the numeric targets shall be submitted by February 15 after the first 5-year period. Thereafter, the report shall be submitted annually by February 15 of each year.

Task 9: Big Bear Lake Multimetric Index Development Plan

No later than (**1 year from effective date of this Basin Plan amendment **), the US Forest Service, the State of California, Department of Transportation (Caltrans), the County of San Bernardino, San Bernardino County Flood Control District, the City of Big Bear Lake, and Big Bear Mountain Resorts, shall, as a group, submit to the Regional Board for approval a proposed plan and schedule for development of a multimetric index for Big Bear Lake. At a minimum, the plan shall include procedures for incorporating biological, chemical and physical parameters to be used for evaluating Big Bear Lake. The plan shall also include sampling recommendations to calculate trophic state, aquatic macrophyte biomass and species, fish assemblages, shore-zone habitat, phytoplankton, and zooplankton for effective assessment. These monitoring recommendations should be integrated with ongoing in-lake and watershed monitoring (Tasks 4.1 and 4.2).

The Big Bear Lake Multimetric Management Plan shall be implemented upon Regional Board approval at a duly noticed public meeting.

In lieu of this coordinated plan, one or more of the parties identified above may submit a proposed individual or group Multimetric Index Development Plan and schedule for approval by the Regional Board. Any such individual or group Plan is due no later than (**1 year from effective date of this Basin Plan amendment**) and shall be implemented upon Regional Board approval at a duly noticed public meeting.

Task 10: Review and Revision of Water Quality Objectives

By December 31, 2010, the Regional Board shall review and revise as necessary the total inorganic nitrogen and total phosphorus numeric water quality objectives for Big Bear Lake. The Regional Board shall also consider the development of narrative or numeric objectives for other indicators of impairment (e.g., chlorophyll *a*, macrophyte coverage and species composition), in lieu of or in addition to review/revision of the numeric objectives for phosphorus and nitrogen. Given budgetary constraints, completion of this task is likely to require substantive contributions from interested parties.

Task 11: Review of Big Bear Lake Tributary Data

No later than December 2008, the Regional Board shall review data collected on Rathbun Creek, Summit Creek and Grout Creek to determine whether beneficial uses of these tributaries are impaired by nutrients. If the Creeks are found to be impaired by nutrients, the Regional Board shall develop a TMDL development project plan and schedule.

If these tributaries are found not to be impaired by nutrients, Regional Board shall schedule the delisting of the tributaries from the 303(d) list of impaired waters at the earliest opportunity.

Task 12: Development of TMDL for Average and/or Wet Hydrological Conditions

No later than December 31, 2012, the Regional Board shall utilize additional water quality data and information collected pursuant to monitoring program requirements (Tasks 4 and 5) and model updates (Task 6) to develop proposed nutrient TMDLs for Big Bear Lake for average and/or wet hydrological conditions.

Task 13: Review/Revision of the Big Bear Lake Dry Hydrological Conditions Nutrient TMDL (TMDL "Re-opener")

The basis for the Dry Hydrological Condtions TMDLs and implementation schedule will be re-evaluated at least once every three years[1] to determine the need for modifying the allocations, numeric targets and TMDLs. Regional Board staff will continue to review all data and information generated pursuant to the TMDL requirements on an ongoing basis. Based on results generated through the monitoring programs, special studies and/or modeling analyses, changes to the TMDLs may be warranted. Such changes will be considered through the Basin Plan Amendment process.

The Regional Board is committed to the review of these TMDLs every three years, or more frequently if warranted by these or other studies.

References

1. California Regional Water Quality Control Board, Santa Ana Region. Staff Report on the Nutrient Total Maximum Daily Loads for Big Bear Lake, May, 2005.

[1] The three-year schedule is tied to the 3 year triennial review schedule.

ATTACHMENT B
ENVIRONMENTAL CHECKLIST

I. BACKGROUND

1. **Project title:** *Basin Plan amendment to incorporate Nutrient TMDLs for Big Bear Lake in the Big Bear Lake Watershed*

2. **Lead agency name and address:** *California Regional Water Quality Control Board, Santa Ana Region, 3737 Main Street, Suite 500, Riverside, CA 92501-3348*

3. **Contact person and phone number:** *Hope Smythe (951) 782- 4493*

4. **Project location:** *Big Bear Lake Watershed, San Bernardino County (all portions of the City of Big Bear Lake)*

5. **Project sponsor's name and address:** *California Regional Water Quality Control Board, Santa Ana Region, 3737 Main Street, Suite 500, Riverside, CA 92501-3348*

6. **General plan designation:** *Not applicable*

7. **Zoning:** *Not applicable*

8. **Description of project:** *Adoption of a Basin Plan amendment to incorporate Nutrient TMDLs for Big Bear Lake. The TMDLs establish wasteload allocations and load allocations for allowable nutrient inputs by all identified sources that discharge to Big Bear Lake. The intent is to achieve numeric, water quality targets that will protect the beneficial uses of the lake. The Basin Plan amendment includes an implementation plan that details the actions required by the Regional Board and other responsible parties for implementing the TMDLs.*

9. **Surrounding land uses and setting:** *Not applicable*

10. **Other public agencies whose approval is required:** *The Basin Plan amendment must be approved by the State Water Resources Control Board, the Office of Administrative Law, and the U.S. Environmental Protection Agency before it becomes effective.*

ENVIRONMENTAL FACTORS POTENTIALLY AFFECTED:
The environmental factors checked below would be potentially affected by this project, involving at least one impact that is a "Potentially Significant Impact" as indicated by the checklist on the following pages.

☐ Aesthetics	☐ Agricultural Resources	☐ Air Quality
☐ Biological Resources	☐ Cultural Resources	☐ Geology/Soils
☐ Hazards & Hazardous Materials	☐ Hydrology / Water Quality	☐ Land Use / Planning
☐ Mineral Resources	☐ Noise	☐ Population / Housing
☐ Public Services	☐ Recreation	☐ Transportation / Traffic
☐ Utilities / Service Systems	☐ Mandatory Findings of Significance	

II. DETERMINATION

On the basis of this initial evaluation:

X I find that the proposed project COULD NOT have a significant effect on the environment.

____ I find that the proposed project MAY have a significant effect on the environment. However, there are feasible alternatives and/or mitigation measures available that will substantially lessen any adverse impact. These alternatives are discussed in the attached written report.

____ I find that the proposed project MAY have a significant effect on the environment. There are no feasible alternatives and/or feasible mitigation measures available that would substantially lessen any significant adverse impact. See the attached written report for a discussion of this determination.

______________________________ ______________________________
Signature Date

Hope Smythe
Senior Environmental Specialist

III. ENVIRONMENTAL IMPACTS

CEQA Checklist

Question	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
I. AESTHETICS - Would the project:				
a) Have a substantial adverse effect on a scenic vista?			X	
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?				X
c) Substantially degrade the existing visual character or quality of the site and its surroundings?				X
d) Create a new source of substantial light or glare that would adversely affect day or nighttime views in the area?				X
II. AGRICULTURE RESOURCES: In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Dept. of Conservation as an optional model to use in assessing impacts on agriculture and farmland. Would the project:				
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use?				X
b) Conflict with existing zoning for agricultural use, or a Williamson Act contract?				X
c) Involve other changes in the existing environment that, due to their location or nature, could result in conversion of Farmland, to non-agricultural use?				X
III. AIR QUALITY - Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. Would the project:				
a) Conflict with or obstruct implementation of the applicable air quality plan?				X
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?				X
c) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient				X

CEQA Checklist

Question	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors)?				
d) Expose sensitive receptors to substantial pollutant concentrations?				X
e) Create objectionable odors affecting a substantial number of people?				X
IV. BIOLOGICAL RESOURCES - Would the project:				
a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?			X	
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, and regulations, or by the California Department of Fish and Game or US Fish and Wildlife Service?			X	
c) Have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means?				X
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?			X	
e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?				X
f) Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other approved local, regional, or state habitat conservation plan?				X
V. CULTURAL RESOURCES - Would the project:				
a) Cause a substantial adverse change in the significance of a historical resource as defined in ¤15064.5?				X
b) Cause a substantial adverse change in the significance of an archaeological resource pursuant to ¤15064.5?				X
c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?				X

CEQA Checklist

Question	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
d) Disturb any human remains, including those interred outside of formal cemeteries?				X
VI. GEOLOGY AND SOILS - Would the project:				
a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:				X
i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42.				X
ii) Strong seismic ground shaking?				X
iii) Seismic-related ground failure, including liquefaction?				X
iv) Landslides?				X
b) Result in substantial soil erosion or the loss of topsoil?				X
c) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on-site or off-site landslide, lateral spreading, subsidence, liquefaction or collapse?				X
d) Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?				X
e) Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water?				X
VII. HAZARDS AND HAZARDOUS MATERIALS - Would the project:				
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?				X
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?				X
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?				X

CEQA Checklist

Question	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?				X
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard for people residing or working in the project area?				X
f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?				X
g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?				X
h) Expose people or structures to a significant risk of loss, injury or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?				X
VIII. HYDROLOGY AND WATER QUALITY - Would the project:				
a) Violate any water quality standards or waste discharge requirements?				X
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?				X
c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner that would result in substantial erosion or siltation on-site or off-site?				X
d) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on-site or off-site?				X
e) Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?				X
f) Otherwise substantially degrade water quality?				X
g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?				X

CEQA Checklist

Question	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
h) Place within a 100-year flood hazard area structures that would impede or redirect flood flows?				X
i) Expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam?				X
j) Inundation by seiche, tsunami, or mudflow?				X
IX. LAND USE AND PLANNING - Would the project:				
a) Physically divide an established community?				X
b) Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?				X
c) Conflict with any applicable habitat conservation plan or natural community conservation plan?				X
X. MINERAL RESOURCES - Would the project:				
a) Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?				X
b) Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?				X
XI. NOISE - Would the project result in:				
a) Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?				X
b) Exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?				X
c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?				X
d) A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?			X	
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project expose people				X

CEQA Checklist

Question	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
residing or working in the project area to excessive noise levels?				
f) For a project within the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?				X
XII. POPULATION AND HOUSING - Would the project:				
a) Induce substantial population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?				X
b) Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?				X
c) Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?				X
XIII. PUBLIC SERVICES				
a) Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times or other performance objectives for any of the public services: Fire protection? Police protection? Schools? Parks? Other public facilities?				X
XIV. RECREATION - Would the project:				
a) Increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?				X
b) Does the project include recreational facilities or require the construction or expansion of recreational facilities that might have an adverse physical effect on the environment?				X
XV. TRANSPORTATION/TRAFFIC - Would the project:				
a) Cause an increase in traffic that is substantial in relation to the existing traffic load and capacity of the street system (i.e., result in a substantial increase in either the number of vehicle trips, the volume to capacity ratio on roads, or congestion at intersections)?			X	

CEQA Checklist

Question	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
b) Exceed, either individually or cumulatively, a level of service standard established by the county congestion management agency for designated roads or highways?				X
c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location that results in substantial safety risks?				X
d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?				X
e) Result in inadequate emergency access?				X
f) Result in inadequate parking capacity?				X
g) Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., bus turnouts, bicycle racks)?				X
XVI. UTILITIES AND SERVICE SYSTEMS – Would the project:				
a) Exceed wastewater treatment requirements of the applicable Regional Water Quality Control Board?				X
b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?				X
c) Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?			X	
d) Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed?				X
e) Result in a determination by the wastewater treatment provider that serves or may serve the project that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?				X
f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?				X
g) Comply with federal, state, and local statutes and regulations related to solid waste?				X
XVII. MANDATORY FINDINGS OF SIGNIFICANCE -				

CEQA Checklist

Question	Potentially Significant Impact	Less Than Significant With Mitigation Incorporation	Less Than Significant Impact	No Impact
a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal or eliminate important examples of the major periods of California history or prehistory?				X
b) Does the project have impacts that are individually limited, but cumulatively considerable? ('Cumulatively considerable' means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects)?				X
c) Does the project have environmental effects that will cause substantial adverse effects on human beings, either directly or indirectly?				X

Attachment - Environmental Checklist

Discussion of Environmental Impacts

Explanation of Environmental Checklist "Less than significant" Answers

Note: Adoption of the Basin Plan amendment to incorporate Nutrient TMDLs for Big Bear Lake will not have any direct adverse impact on the environment. Implementation of actions necessary to achieve the TMDLs may affect the environment, as described below. However, the intent of TMDL implementation is to restore and protect the water quality of the lake and its beneficial uses. Any potential adverse environmental effects associated with TMDL implementation will be subject to project-specific CEQA analysis and certification to assure appropriate avoidance/minimization and mitigation.

I. Aesthetics (a)

The proposed TMDLs call for reductions in nutrient loads to the lake, which may include the implementation of BMPs that could be aesthetically unpleasing.

IV. Biological Resources (a), (b), (d)

The proposed TMDLs call for actions to reduce internal nutrient loading to the lake, which may include the application of aluminum sulfate (alum), fishery management, macrophyte management and sediment removal. The Big Bear Lake watershed is host to many sensitive species including the Federally-threatened Bald Eagle. Such actions have the potential to affect the biota, including sensitive species. Any such actions are likely to be temporary and in the long-term, would result in the enhancement of Big Bear Lake aquatic habitat utilized by sensitive species.

XI. Noise (d)

Implementation of actions necessary to implement the proposed TMDLs may result in increases in noise levels. However, these effects are expected to be limited in scope and duration and are not considered significant. Again, proposed implementation actions would be subject to specific CEQA analysis and certification.

XV. Transportation/Traffic (a)

Implementation of actions necessary to implement the proposed TMDLs, such as transporting alum to Big Bear Lake and/or removal and disposal of dredge materials, may result in increases in traffic on the two main highways that serve Big Bear Lake. However, these effects are expected to be limited in scope and duration and are not considered significant. Again, proposed implementation actions would be subject to specific CEQA analysis and certification.

XVI. Utilities and Service Systems (c)

The proposed TMDLs call for reductions in nutrient contributions to the lake from internal sources. To achieve these reductions, modifications to the storm drainage system may be necessary. Any such projects associated with storm drainage systems modifications would be subject to further, case-specific environmental review and certification.